NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93943-5002

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

T 5691

A Personal-Computer Based DSS For Diabetes Control and Monitoring

by

Richard A. Blow
and
Steven P. Albert

September, 1989

Thesis Advisor: Professor Moshe Zviran

Approved for public release; distribution is unlimited.

T245589

NCLASSIED
CURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

REPORT SECURITY CLASSIFICATION NCLASSIFIED	1b RESTRICTIVE MARKINGS
SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
DECLASSIFICATION/DOWNGRADING SCHEDULE	
PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
a NAME OF PERFORMING ORGANIZATION aval Postgraduate School	6b OFFICE SYMBOL (*If applicable*) 52
c ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5000	7b ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5000
a NAME OF FUNDING/SPONSORING RGANIZATION	8b OFFICE SYMBOL (*If applicable*)
c ADDRESS (*City, State, and ZIP Code*)	10 SOURCE OF FUNDING NUMBERS

Program Element No	Project No	Task No	Work Unit Accession Number

1 TITLE (*Include Security Classification*)
PERSONAL-COMPUTER BASED DSS FOR DIABETES CONTROL AND MONITORING

2 PERSONAL AUTHOR(S) Blow, Richard, A. and Albert, Steven, P.

3a TYPE OF REPORT	13b TIME COVERED		14 DATE OF REPORT (*year, month, day*)	15 PAGE COUNT
laster's Thesis	From	To	September 1989	115

6 SUPPLEMENTARY NOTATION
he views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. overnment.

7 COSATI CODES			18 SUBJECT TERMS (*continue on reverse if necessary and identify by block number*)
FIELD	GROUP	SUBGROUP	Diabetes Decision Support System

9 ABSTRACT (*continue on reverse if necessary and identify by block number*)

Diabetes is a serious disease that affects many people. The military medical system is one of the largest medical systems in the world, and reats a significant number of dependent diabetics. As with most sections of the military, the medical community is understaffed. This results in nost facilities lacking adequate medical care for these patients. The key to the treatment of diabetes is control of blood glucose levels and the ontributing factors, such as food and exercise. By controlling these factors large fluctuations in the glucose levels can be minimized. A decision upport system that enables both the medical personnel and the patient to manage these factors could vastly improve treatment and mitigate the de effects of diabetes. This paper will address how such an approach can be applied to diabetes resulting in better medical care and decrease the emand on a stressed medical system.

0 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION	
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS REPORT ☐ DTIC USERS	Unclassified	
2a NAME OF RESPONSIBLE INDIVIDUAL Professor Moshe Zviran	22b TELEPHONE (*Include Area code*) (408)646-2489	22c OFFICE SYMBOL 54ZV

D FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Approved for public release; distribution is unlimited.

A PERSONAL-COMPUTER BASED DSS FOR DIABETES CONTROL AND MONITORING

by

Richard A. Blow
Lieutenant Commander, U.S.N.R.
M.S., CORPUS CHRISTI STATE UNIVERSITY, 1984

AND

Steven P. Albert
Lieutenant Commander, U.S.N.
B.S., UNIVERSITY OF TENNESSEE, 1977

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
SEPTEMBER 1989

ABSTRACT

Diabetes is a serious disease that affects many people. The military medical system is one of the largest medical systems in the world, and treats a significant number of dependent diabetics. As with most sections of the military, the medical community is understaffed. This results in most facilities lacking adequate medical care for these patients. The key to the treatment of diabetes is control of blood glucose levels and the contributing factors, such as food and exercise. By controlling these factors large fluctuations in the glucose levels can be minimized. A decision support system that enables both the medical personnel and the patient to manage these factors could vastly improve treatment and mitigate the side effects of diabetes. This paper will address how such an approach can be applied to diabetes resulting in better medical care and decrease the demand on a stressed medical system.

C.1

TABLE OF CONTENTS

I. INTRODUCTION 1

A. BACKGROUND 1

B. WHAT IS DIABETES? 3

C. TREATMENT OF DIABETES 4

D. ONSET AND TREATMENT 9

II. SYSTEM ANALYSIS 12

A. THE NEED FOR INFORMATION 12

B. THE MANUAL SYSTEM 17

C. COMPUTER-BASED SYSTEMS 17

III. DEVELOPMENT TOOLS 21

A. METHODOLOGY 21

B. ROMC AND SYSTEM ANALYSIS 23

C. SYSTEM RECOMMENDATIONS AND DESIGN CONSIDERATIONS 23

D. SOFTWARE SELECTION 25

IV. SYSTEM DESIGN 29

A. INTRODUCTION 29

DUDLEY KNOX LIBRARY
NAVAL
MONT

B. DESIGN OVERVIEW 29
C. SYSTEM COMPONENTS 30
D. REPRESENTATIONS, OPERATIONS, MEMORY AIDS AND CONTROL MECHANISMS 32

V. DISCUSSION AND CONCLUSIONS 48
A. USES OF THE DIABETES SUPPORT SYSTEM 48
B. PARADOX 3.0 PROBLEM AREAS AND ADVANTAGES 50
C. THE DIABETES SUPPORT SYSTEM CONCLUSIONS 52
D. THE FUTURE 53

APPENDIX 54
A. PROGRAM OVERVIEW 54
B. CONTROL MECHANISMS 57
C. MENU SELECTION DETAILS 58

BIBLIOGRAPHY 107

INITIAL DISTRIBUTION LIST 109

I. INTRODUCTION

A. BACKGROUND

There are approximately 2,000,000 people in the United States that have Diabetes Mellitus. Diabetes occurs when the body has insufficient quantities of insulin to process glucose for cell energy. It is characterized by a build-up of glucose in the blood stream and urine. As a result, all parts of the body are exposed to these high levels which can lead to serious complications, chief of which are macrovascular related diseases, such as atherosclerosis, and microvascular diseases that affect every organ. Macrovascular diseases, like heart disease, are a leading cause of death in diabetics (Ellenberg, 1979). Because of these complications, maintaining glucose levels as close to normal as possible is essential in the treatment of diabetes.

The Veterans Administration (VA) and military hospital systems are among the largest medical systems in the world. The uniformed services medical community alone treats thousands of dependents with diabetes each year. With the severe shortage of medical personnel, in both the military and the Veterans Administration, only the larger military hospitals and VA facilities have endocrinologists on staff. Many hospitals (such as Fort Ord), have only a part-time civilian doctor that holds clinics for diabetics once a quarter.

The key to controlling diabetes is close monitoring of glucose levels. With frequent monitoring, fluctuations in glucose levels can be identified early. Using these trends, such as recurring highs or lows, steps can be taken to correct them. Early

detection and analysis of trends promotes tighter control. This allows smaller adjustments in insulin, diet and exercise to be made. Maintaining tight control reduces visits to the doctor and may prevent hospitalization. In addition to promoting good health, most physicians feel that tight control of glucose levels will lead to fewer complications arising later in life. This will reduce the strain on the medical community and improve the quality of life for diabetics.

At the present time, both diabetics and medical personnel (who are not familiar with diabetes treatment) must manually study logbooks of glucose readings, diet plans, food exchange charts, and exercise tables in an effort to sustain their own or their patient's glucose maintenance programs. This is time-consuming and it is frequently difficult to conduct trend analysis and exception reporting with the amount of diverse information needed. If these functions could be provided quickly and easily, they could prove extremely useful in identifying trends and in maintaining control of blood sugar levels. With this system, small hospitals, clinics and individuals could identify trends sooner and make needed changes.

Diabetics and health care professionals must make numerous important decisions daily in the control and maintenance of diabetes. How much and what combination of insulin is required? How many calories to consume? Menus must be planned with the proper balance of fats, carbohydrates and proteins. When to exercise and how much? These are only a few of the daily decisions that need to be made. With the amount and varieties of knowledge needed, a decision support system would help these people make the proper decisions and can be of enormous value in the fight against a serious and tragic disease which robs thousands of people each year of quality of

life, as well as life itself. This paper will address how such an approach can be applied to diabetes.

B. WHAT IS DIABETES?

Every cell of the body requires energy to maintain life and carry on its specific functions. This energy is derived from glucose. Glucose (or sugar), is obtained from carbohydrates contained in foods and is carried by the blood stream to the cells. In order for the glucose to be absorbed into the cells, the hormone insulin is required. Insulin and a number of other hormones are produced in the pancreas. The sites where the insulin is produced are called beta cells. Insulin is essential in regulating the metabolism of glucose into the cell (Travis, 1985).

Diabetes has been divided into two major types, each of which has a number of terms used to describe them. The first type is called Type I, insulin dependent, or juvenile on-set diabetes. Type I diabetes frequently appears in children, although it can appear at any age. Type I diabetes is the primary focus of this project. The second form of diabetes is Type II or adult on-set diabetes. Type II diabetes may or may not be insulin dependent and can sometimes be controlled with diet and exercise. Although this system is focused on insulin dependent diabetes, three of the four applications could be of significant use to Type II diabetics.

In Type I diabetes the immune system, for unknown reasons, destroys the beta cells. The destruction of these beta cells results in little or no insulin being produced by the pancreas. Without insulin, the ability to transport glucose into the cell is lost. The cells, in their quest for energy, will use fat stores in order to obtain this needed energy. As fats are converted into energy, ketones are produced in the liver which

build up in the blood stream. This can lead to diabetic acidosis, a serious condition which can result in death.

In a normal person, the glucose level is maintained, on the average, within a narrow range of 60-80 milligrams/ decaliter (mg/dl) by a complex combination of organs and hormones. Type I diabetics must manually maintain their glucose levels with daily injections of artificially produced insulin. As a result of not being able to produce insulin, on an as-needed basis, diabetics must try to keep their glucose levels, as close to normal as possible, artificially. In order to maintain stable glucose levels a combination of diet, exercise, blood monitoring and insulin injections are required.

Diabetes is a complex disease and the complications have far reaching effects on the individual and his or her life style. Atherosclerosis develops at an accelerated rate in diabetes and heart disease is the leading cause of death in diabetics. Microvascular diseases affect the small vessels of the blood stream causing damage to the organs such as the eyes, kidneys, gastrointestinal tract and circulation in the lower extremities. Diabetes is the major cause of blindness and amputation in the United States today (Ellenberg, 1979).

C. TREATMENT OF DIABETES

In 1948, the medical community recognized that the incidence of secondary complications might be reduced if blood glucose levels could be closely monitored and controlled. Today, it is possible for diabetics to monitor their glucose levels at home using fast, accurate and reliable self-testing procedures. Individuals can then compare their glucose readings with a range of clinically determined values that are considered normal. With careful monitoring, a diabetic can adjust his/her daily insulin dosages

to a level that will keep blood glucose values within this normal range. However, many factors can affect the delicate balance of glucose and insulin in the blood. Diet and exercise are among the most important of these regulatory factors (Figure 1).

Blood monitoring is a complex process which requires the management of insulin dosages, insulin types and analysis of blood samples taken by the individual. There are a number of regimens of blood monitoring and insulin injections, ranging from loose control of 1 to 2 blood samples per day and 1 injection to a tight control of 4 or more samples and two or more injections a day. One of the frequently used schedules consists of 2 injections and 3 to 4 blood samples per day. In this routine the individual takes a small sample of blood from his finger and uses a glucose reactive chemical test strip to determine the amount of glucose present in the blood stream. This information is used to determine insulin dosages, dietary intake and exercise requirements. These complex factors are only a few of the aspects of diabetes control.

There are three basic insulin categories: rapid acting, intermediate acting, and long acting. Each category is based on the effective activity time. A normal insulin dosage is usually made up of a combination of slower acting NPH (Isophane) and faster acting regular (crystalline insulin). The slow acting insulin begins to react in 1 hour, peaks in 8 to 12 hours and is gone within 20 to 24 hours. The other, regular insulin is fast acting and starts working in about 1/2 hour and peaks from 2 to 3 hours later being completely used in 4 to 6 hours (Table I).

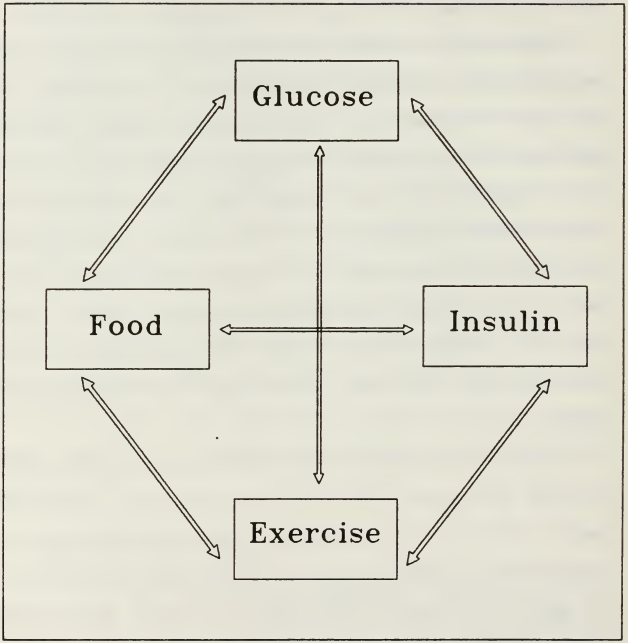

Figure 1 Factors Affecting Glucose Balance

Table I INSULIN TYPES

1.) Rapid acting:

Takes effect - 0.5 to 1.0 hrs
Most effective - 2.0 to 3.0 hrs
Depleted - 4.0 to 6.0 hrs

2.) Intermediate acting:

Takes effect - .5 to 1.0 hrs
Most effective - 5.0 to 7.0 hrs
Depleted - 12.0 to 16.0 hrs

3.) Long acting:

Takes effect - 1.0 to 1.5 hrs
Most effective - 8.0 to 12.0 hrs
Depleted - 20.0 to 24.0 hrs

Adapted from Travis, 1985

Dietary requirements include daily caloric intake which must be strictly controlled, another important factor in the control of glucose levels. This requires the diabetic to eat a number of smaller meals at specified times throughout the day in order to maintain a relatively consistent glucose level in the blood stream to avoid glucose peaks and valleys. In a non-diabetic, the body can very quickly raise or lower the glucose level in response to the demands placed on it by food intake, stress, illness or a number of other forces. A diabetic, on the other hand, can not regulate the glucose levels as quickly, because insulin injected requires time to be absorbed by the body. Nor can the glucose level be maintained as accurately by manual means. In the non-diabetic insulin is produced on an as-needed basis, whereas in diabetics

quantities of insulin are injected at specified times and it is dependent on the number of injections, type of insulin, diet and amount of exercise to maintain glucose levels within a specified range. "Good" control of glucose levels in a diabetic is considered to be between 60-150 mg/dl (Travis, 1985).

The type of foods (such as carbohydrates, fats and proteins) must be carefully monitored to keep the blood sugar levels consistent. This requires the diabetic to know not only the number of calories a food item contains, but also the makeup of these foods. In order for the diabetic to manage a proper diet; food exchange charts are used in meal planning to achieve the balance required. Food exchange charts give group foods by type, relative makeup and portions. This information, along with calorie charts and dietary plans gives the diabetic a basis for daily food intake requirements.

Another important factor in regulating the amount of glucose in the blood stream is exercise. Daily exercise is important for a number of reasons. One reason is that exercise is important in maintaining body weight. Obesity compounds the problem of diabetes by increasing the amount of insulin required to maintain glucose levels and is a major contributor to Type II diabetes. High levels of fat in the blood stream also can contribute to atherosclerosis, the building up of deposits in the arteries. Exercise increases the body's ability to use glucose and reduces the need for insulin. Therefore, exercise is extremely beneficial to the diabetic. But, at the same time, exercise must be closely monitored to avoid an insulin reaction due to too low a glucose level.

Diabetes affects the body in many ways, especially the circulatory system. As a result poor control diabetics have a significantly higher incidence of: coronary

disease, liver damage, blindness and poor blood circulation. Extreme cases may develop gangrenous infections that often result in the amputation of limbs. Secondary infections and other disease-related complications claim the lives of 20,000 diabetics each year.

Finally, terminology is another problem associated with any medical condition. Diabetes is no exception and in fact requires knowledge of a wide variety of medical terms, covering many aspects of the body and a number of diseases. There are also a number of terms from dietetic and exercise terminology that need to be understood. Terminology can become a barrier to understanding by individuals, as well as between medical personnel and patients (Figure 2).

D. ONSET AND TREATMENT

As with any disease, effective treatment for Juvenile-Onset Type I, diabetes mellitus begins with proper diagnosis. The disease typically appears in the growth and puberty years; however, onset may occur at any age. Symptoms often appear quite dramatically, and in many cases the patient may require initial hospitalization. Frequently, in small children, the disease becomes critical before a doctor is consulted and requires hospitalization until a positive diagnosis is made and the patient is stabilized. The causal factors may be genetic and/or precipitated by an unknown factor. The primary determinant of Type I Diabetes is the inability of the patient's pancreas to produce insulin.

Once this diagnosis is confirmed, the attending physician, usually an endocrinologist, conducts a series of tests to establish a baseline for developing a treatment regimen. The primary goal of an effective regimen is to monitor and control

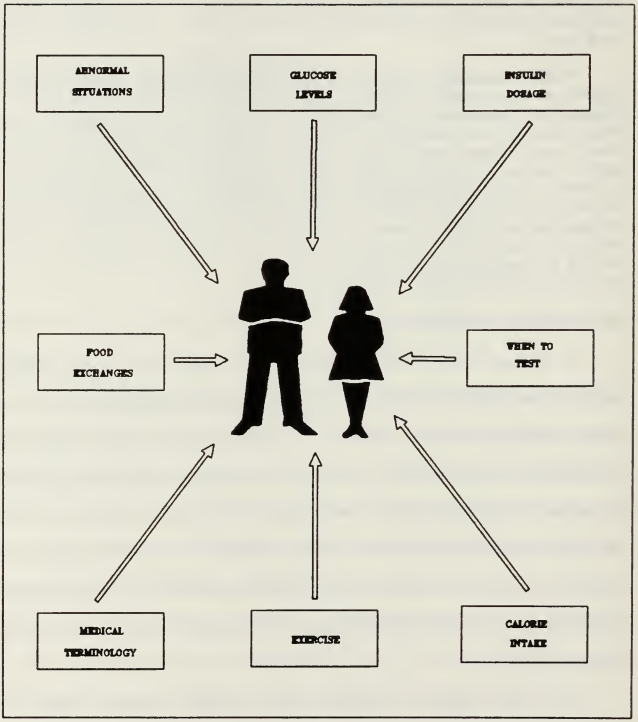

Figure 2 Decisions for Diabetics

the level of glucose in the blood stream. The term control in this context refers to the degree that a diabetic manages to keep his/her blood glucose level within a specified range. The "acceptable range" is generally considered to be 60 to 180 mg/dl (Travis, 1985) however, diabetics are encouraged to strive for the "good control" of 80 to 120 mg/dl. This usually requires a strict regimen and close monitoring on behalf of the individual.

The success of a treatment regimen is strongly influenced by the following considerations:

1. A positive and cooperative attitude toward treatment.
2. A thorough education on the fundamentals of diabetes control.
3. The design and implementation of a treatment program that is stringent enough to maintain control, and at the same time flexible enough to provide the diabetic with the means to live as normal a life as is possible.

The complexity of diabetes and wide nature of knowledge needed to maintain and control the disease, is an area that could vastly benefit from an automated decision support system and is the focus of this system.

II. SYSTEM ANALYSIS

A. THE NEED FOR INFORMATION

The previous sections have shown that diabetes is a complicated disease and requires a wide variety of knowledge to properly control and maintain. The volume and diversity of the information can quickly overwhelm the new diabetic. One of the biggest problems is finding the information that can answer a specific question. With the new diabetic, a vast amount of information is provided in a short period of time, when the patient is first diagnosed. At this time the diabetic is under great stress and is undergoing various stages of fear and denial. This leaves the patient's learning ability and retention severely limited. Also the sheer volume of information needed overwhelms the diabetic and further increases anxiety. The diabetic feels that he will never learn what is needed or he might make a mistake that could cause serious complications or even death. The first few weeks is also a time when the physician, dietician and nursing staff are inundated with frequent phone calls for basic information (Travis, 1985).

Even after the diabetic feels comfortable with the day-to-day maintenance of his disease, the individual must cope with a myriad of decisions daily. Although diet, exercise and insulin are interrelated the decisions can be grouped around these themes. The following are only a few of the decisions that are required:

1. Insulin regimen and blood glucose levels.
   a. Blood glucose level must be checked regularly. The resultant readings will affect insulin dosage, insulin types and frequency of testing. If the readings

indicate the glucose levels are within normal ranges, normal insulin dosages, diet and exercise programs can be maintained. If not within normal range the diabetic must discover if a trend exists.

b. If the trend indicates a very low value (less than 60 ml/dl), consistent low readings either over a period of time or repeatedly at the same time daily, action should be taken.. A number of choices must be made depending on which of the three indications exist. A very low reading may be an indication of Hypoglycemia and the glucose level must be raised, usually by consuming a small amount of sugar immediately. If the readings occur repeatedly, then a modification of the insulin dosage by lowering one of the types of insulin may be required.

c. If the readings indicate glucose levels above normal (greater than 150 ml/dl), modifications of dosages and types may be required by increasing either amounts or types of insulin. With high readings concern arises about Hyperglycemia and Keto-acidosis. Urine samples may need to be monitored for Ketones.

2. A suitable diet plan.

a. The individual's food preferences -- This is an extremely important consideration. Successful dietary control hinges on acceptance by the diabetic. Every effort should be made to accommodate food preferences within the allowable constraints imposed by the disease.

b. Age, sex and body weight -- The dietary goal is to develop a meal planning methodology that provides the nutritional and total caloric intake for an individual based on age, sex and body weight.

c. Consistent food intake -- Of the three major regulatory factors (diet, insulin and exercise), food and insulin have the most dramatic effect on glucose levels. It is impossible to stabilize insulin levels if food intake fluctuates from day to day.

3. Food Exchanges Charts

a. The Exchange Diet methodology -- This approach to diet planning divides foods into six categories on the basis of fat, protein and carbohydrate intake. It provides standard measures for food serving sizes. Each measure is described in terms of total calories and nutrient content. All foods contained in a particular category can be exchanged for any other food in that category on a one for one basis. For example, 1 slice of bread or 3/4 cup of dry cereal both equal 1 Bread Exchange. The six major food exchanges are:

- Milk Exchange
- Fruit Exchange
- Vegetable Exchange
- Starch (Bread) Exchange
- Protein (Meat) Exchange
- Fat Exchange

b. Carbohydrate intake -- Carbohydrates have the most profound effect on blood glucose levels and insulin requirements. This is due to the fact that carbohydrates are composed of sugars (glucose and/or derivatives of). Therefore, it is imperative that carbohydrate intake stay constant. Three of the six food exchanges contain significant amounts of carbohydrates:

- Starch Exchange
- Fruit Exchange
- Milk Exchange

c. Protein and fat intake -- These two components are required for proper nutrition. However, they do not directly affect glucose level in the blood. (Travis, 1985)

4. Exercise management

a. Lack of exercise can cause an increase in body weight thus causing an increase in the amount of insulin required. Cholesterol levels are affected by the amount of exercise. With inactivity, cholesterol levels may increase and increase the risk of arterial disease.

b. Excessive exercise can cause the insulin to be absorbed too quickly causing a drastic drop in blood glucose levels and leading to hypoglycemia.

These are only a few of the decisions required to maintain a diabetic every day; many of these issues can be critical. The diverse nature and frequency of these decisions can be overwhelming for both the diabetic and the health care professional, especially if not a specialist in the field. An automated system could vastly improve

the quality of diabetic care over the present, mostly manual, system by providing a number of features to aid the diabetic in the management and control of this disease. The better the control of glucose in the blood stream the less likely there will be secondary complications in the future.

The physician or a health care professional and dietician teach the diabetic the basics and some of the skills of how to maintain effective control. These instructions include the principles of the food exchange diet methodology for blood glucose control, calorie intake diet control and menu preparation. Exercise programs may also be discussed in general terms with the understanding that the patient will set up a personal program. A diabetic, normally, will visit the physician and dietician once every three months for a progress review. The physician conducts a test of Hemoglobin A1c at this time. This test will give an indication of the overall blood glucose levels for the preceding three months. On the basis of patient progress review, the physician and dietician may make recommendations and modifications to the treatment reinforcing certain ideas.

The bottom line is the diabetic must assume responsibility for daily monitoring and control of his disease using instructions and materials provided by the physician and dietician. A system that centralizes the needs of both the patient and the physician could improve the effectiveness of the efforts of each.

By organizing and centralizing the diverse information requirements, both the patient and the physician can work together more effectively. A dictionary is important for communications; physicians frequently use medical terms, to specify exactly, certain ideas and conditions. The patient, may or may not understand these terms or forget

the specifics. By having an electronic dictionary available, more accurate information can be exchanged between the physician and the patient. It also gives a reference source for the patient to questions that might go unanswered or forgotten at the quarterly reviews.

An electronic logbook with a query capability is needed to provide both the patient and physician the ability to quickly spot trends and areas where action is required. On a daily, weekly and/or monthly basis the patient can easily review glucose reading, insulin dosages and changes for trends to better control and maintain tight control. The physician, in the short time available during an appointment, can better determine what is needed and give positive reinforcement where appropriate. This will give more time for personal contact and to answer specific questions, thus making the visit more meaningful for both the patient and doctor.

A central meal planning capability is also needed to gather all the different information needed together for consistent and effective dietary control. There are so many diverse requirements involved in meal planning that a central meal planner could improve control immensely. It will also provide a record for the physician and dietician to make fine adjustments to the individual's diet.

The same philosophy applies to an exercise planner. The easier and more accurate it is for the physician, the better the medical care. The easier it is for the patient, the more likely he is to stick to the treatment program.

As a diabetic learns how to manage the disease he gains confidence and the calls to his physician decrease. But there still is a requirement for information. As a diabetic becomes more informed, he wants to know more and take charge of his life.

The way to do this is through information. The problem is the diverse nature of the information. There is no central location where the individual can go for information about diet, food exchanges, meal plans, exercise and medical terms. Even at the clinic, the diabetic may need to see a physician, a dietician and the nursing staff to answer various questions. There is also the problem of maintaining the records needed to track glucose readings, external influences that affect them, insulin dosages, time and location of injections.

An informed patient is a healthier patient, reducing the medical burden and saving financial resources. Some of the current systems available will be reviewed below.

B. THE MANUAL SYSTEM

The current system, used by most diabetics, is a manual system. A written log is maintained to record glucose readings, times of the readings and insulin dosages. A record is also needed to record daily occurrences such as meals, exercise and any variations, such as illness or stress. A food exchange booklet and calorie charts are needed to plan meals and monitor food intake.

C. COMPUTER-BASED SYSTEMS

At this time there are four data management systems available to the public, these systems are listed in Table II (Feder, 1988). A review of some of the available computer-based systems revealed two important points. First, there is a move towards this type of system, with new systems being marketed almost monthly. Second, at present there is no system that has incorporated all the features needed by the diabetic (i.e. Logbook with trend analysis, Nutrition information including Food Exchange

Table II - DIABETES DATA MANAGEMENT SYSTEMS

SYSTEM	MANUFACTURER	OPTIONS
Data Manager	LifeScan	Logbook
Glucometer M	Miles	Logbook
Merlin	Boehringer Mannheim	Logbook
Romeo	Diva	Logbook, Limited Nutrition, Exercise

Charts and USDA Nutrition charts, Exercise information and a Dictionary of relevant terms). The features that are needed include:

1. Electronic Logbook for tracking and analysis of glucose readings, insulin dosages, date and time of injections. Patient Database contains back ground medical information.
2. Nutrition information to include exchange charts, nutrition charts and meal planning information.
3. Exercise information to aid in exercise planning.
4. Dictionary to provide definitions of medical and diabetic terminology.
5. Help on-line.

One of the leading diabetes management systems, the Merlin system by Boehringer/Mannheim, was acquired and evaluated. The hand held unit connects to the Accu-Chek II. The Accu-Chek II can be used with the glucose test strips to electronically read the glucose level. This allows the glucose reading to be automatically entered when the blood test is conducted. The system provides the patient with an electronic logbook (of limited storage memory capability of

approximately 2500 glucose readings). The logbook holds glucose readings, insulin dosages, date and time of injections. The unit also allows codes to be entered to explain abnormal readings.

The systems reviewed, both in the literature and with actual testing, did not address all the needs of a diabetic. The Merlin Diabetes Data Management System is available to manage and graph the data, at additional cost, (Boehringer Mannheim, 1988). The system includes a patch cord to upload the data in the Merlin unit to a personal computer and the associated software for either an EGA or CGA monitor. The software allows patient records with limited background information to be maintained. Various graphs and trend analysis functions are available through menu selections. Types of trend analysis include graphs of glucose readings by meal, day of week as well as providing standard deviation and mean values. All of the graphs and charts can be displayed on the terminal or sent to a printer. The advantages and disadvantages are listed in Table III.

With the exception of the Diva system, all of the other units have limited memory available for glucose reading storage. Also only the Diva system had any information on nutrition or exercise. The Diva system was the most comprehensive, but was the most complicated requiring three different units, at a cost of over $1100. Finally, none of the units had a dictionary of diabetic terms or provided the necessary nutrition information and charts required for comprehensive diet planning and control. Additionally, none of the systems allowed for ad hoc query of the database. A more comprehensive system was needed to provide the diabetic with the necessary tools for comprehensive control and management.

Table III - MERLIN SYSTEM EVALUATION

Advantages
Automatic Glucose Data Entry into Unit Memory
Excellent Trend Analysis
Disadvantages
Can Not Enter Data Into Computer Manually
Hand-Held Unit Has Limited Memory
Separate Purchase of Merlin and PC Software Cost
No Nutrition or Exercise Information
Replacement Battery and Patch Cord Difficult to obtain
Need to Remember Exception Codes
Lack of Flexibility

III. DEVELOPMENT TOOLS

A. METHODOLOGY

A review of the systems development literature and the nature of this problem (semi-structured decisions) indicated that a Decision support System (DSS) approach was best suited to the task at hand. Furthermore, it was concluded that the best design approach was to develop the Decision Support System (DSS) utilizing the ROMC (Representations, Operations, Memory Aids and Control Mechanisms) technique described by Sprague and Carlson (1982) coupled with prototyping. This decision was based on the users' requirements (integrated decision support or specific decisions) and the project's constraints. The major constraints include:

1. Limited programming expertise of the builders.
2. The requirement to provide a "user friendly" working prototype within six months. This was based on the premise that many of the users will have limited computer experience.
3. The requirement to deliver a system that would provide a useful decision support system and enhance user productivity. The system had to appeal to physicians, dieticians and diabetic users.
4. The requirement to identify and apply advanced technology to solve a complicated project and show proof of concept.

1. ROMC and Prototyping

The ROMC approach is suitable for this type of project. It is an iterative process that is characterized by prototyping. ROMC gives a builder the flexibility to design a Decision Support System without needing to first identify all of the user's

decision-making processes. Sprague and Carlson (1982) point to other advantages that include:

1. Help DSS builders and users to segment the decision problem and identify the relevant intelligence, decision and choice of operations.

2. Allow the builder to design a set of representations with associated operations, rather than a set of operations that result in representations.

Prototyping, through the process of iteration, allows the builder to construct and deliver to the user a working model, at the least expense, early in the development process. Together, the builder and user can refine the model with each successive iteration. This process promotes maximum user participation throughout the development process and provides maximum flexibility for incorporating changes.

2. The Development Process

Within the framework of the DSS approach, the project was divided into three phases:

1. A preliminary feasibility study -- Based on interviews with prospective users (physicians, medical support personnel and diabetics), a literature review and interviews with commercial software developers, it was concluded that the proposed system was feasible, if new software technology was applied.

2. System analysis and requirements definition -- From the feasibility study, it was determined that the need existed for this system. On that basis, more interviews and an analysis of the current system were conducted. The analysis identified several decisions that could benefit from a Decision Support System.

3. Prototype development -- Using this technique and ROMC conventions, an initial paper prototype and design specifications for the system were identified. Once approved, the coding phase was initiated using a sophisticated fourth generation commercial software package. The iterative process was continued through the third iteration.

B. ROMC AND SYSTEM ANALYSIS

ROMC provides a process independent methodology for defining, analyzing, designing and constructing decision support systems. Sprague and Carlson (1982) view this feature as being among the most important characteristics of the ROMC approach.

Process independence allows the builder to analyze and establish the user's requirements with no prior commitment to the user(s) decision making style. This is extremely significant when considering the fact that most users cannot adequately describe their decision making process.

Sprague and Carlson note that users most often use visual cues (pictures, graphs and charts) when formulating a decision. Based on this knowledge, ROMC provides the perfect vehicle for analyzing user requirements for decision support systems.

Applying these conventions to the Diabetes Support Systems produced the general system requirements listed in Table IV.

C. SYSTEM RECOMMENDATIONS AND DESIGN CONSIDERATIONS

Interviews with diabetics and physicians, in conjunction with observations and discussions at Stanford Childrens Medical Clinic, indicate that there is interest in a computerized diabetes system, provided the following basic design considerations are maintained:

1. Automate the collection and storage of glucose readings and insulin dosages.
2. Provide graphical displays of blood glucose levels for trend analysis, exception reporting and diagnostic control.
3. Provide the ability to display/print food exchange charts as an aid for meal planning.

4. Provide an automated menu planning function. This will allow the user to select foods from a food exchange database and input those values directly into

Table IV ROMC Systems Requirements

Representations

1. An electronic logbook for storing insulin doses/glucose readings.
2. Trend analysis bar/scatter graphs depicting glucose levels (screen displays and printed graphs).
3. Food exchange charts for menu planning (screen displays and printed reports)
4. A menu planning template (screen display design workspace).
5. Printed daily menus.
6. Food composition charts for reference (screen display and printed reports).
7. A medical reference dictionary (screen display)
8. Exercise activity charts depicting caloric expenditure (screen display and printed report).

Operations

The following functions: view, edit, data entry, graph, delete, insert, save, query, print and table lookup.

Memory Aids

Online help, screen message prompts, menu selection descriptions, a workspace for menu planning, table lookup and various views of the data base.

Control Mechanisms

Menu driven control, data validity checking, standard function key assignments and table lookup capability.

daily menus that can be stored and/or printed. The menus should provide calorie, nutrient, serving size and exchange information.

5. Provide a user-friendly ad hoc dictionary of relevant medical and diabetic terms.

6. Provide exercise charts that display caloric expenditure for various activities based on body weight.

D. SOFTWARE SELECTION

To be successful and meet the needs of the user, the system had to consolidate a variety of diet, exercise and medically related diagnostic information as well as provide a wide range of functional capabilities. During the feasibility study, the scope of the project was discussed with the director of software development for Boehringer Mannheim (Merlin Diabetes Monitoring System) and Dr. David Rodbard at the National Institute of Health. Dr. Rodbard and his colleagues were among the early pioneers in the development of software for monitoring diabetes. Both gentlemen stated that this project was probably not possible in terms of budget, personnel and development time. However, it should be noted that Boehringer Mannheim and Dr. Rodbard used third generation programming languages to develop their respective systems (compiled Basic and Pascal respectively). Based on these interviews, and the project's constraints, it was decided that the only feasible way to accomplish the task was to identify and utilize a state-of-the-art fourth generation software package. The software features considered essential to development were:

1. A microcomputer based product.

2. A DBMS, preferably relational.

3. An application generator.

4. A form generator.
5. A report generator.
6. A programming language.
7. Graphics capability.

1. PARADOX 3.0

After a thorough review of leading edge software products (based on software demonstrations and review of the major industry trade journals and periodicals), Borland's Paradox 3.0 was selected. This product was a significant update of an earlier version, Paradox 2.0. In addition to meeting the selection criteria, Paradox 3.0 categorically out-performed all the competition (DBase IV, Enable etc.) in software comparison reviews conducted by the leading periodicals. (Miastkowski and Baran, 1989 and Personal Computing Buyer's Guide)

Paradox 3.0 is a microcomputer-based relational database management system. It is compatible with both the DOS and OS2 operating systems. It supports stand-alone, as well as network operations.

The software package consists of primarily two individual programs, Paradox 3.0 DBMS and the Personal Programmer. Three auxiliary programs, Custom Configuration, Data Toolkit Entry and Pal Programming Language, give the builder access to more advanced procedures for customizing applications. Borland also provides a supplementary package, Paradox Runtime, that allows programs that are developed with Paradox and/or the Personal Programmer to execute as stand-alone applications.

Paradox 3.0 is a menu driven system designed for use by individuals at all levels of experience. No programming expertise is required to develop applications since Paradox has its own application generator. However, applications can be significantly enhanced through the use of Paradox's, Ascii based, Pal Programming Language and the Data Entry Toolkit.

Paradox objects (tables, forms, reports and graphs) are constructed within the Paradox Program. A flexible form and report generator provide the means to design customized products. Both support linked/unlinked and single/multi-table presentations. Paradox offers the flexibility of performing data entry, update, modification and output functions via custom forms and reports or directly to/from the relations themselves.

The Paradox Personal Programmer provides the means to generate Paradox style menus, and allows the user to connect objects, previously constructed in Paradox DBMS, to a variety of menu functions. The available menu selection actions include: view, edit, report, dataentry, query, graph, print and scripts play (executes custom procedures). The application can also be used to generate prototype code that can be modified and enhanced through the use of Pal programming language.

Query-by-example (QBE) allows virtually unlimited ability to select items from the tables and create customized views of individual or multiple tables within the DBMS. However, for stand-alone applications, queries must be predefined. This requires close user/builder communication to ensure the useful views are constructed. Additionally, the QBE feature allows the user to select and sort data in individual fields in ascending or descending order.

In summary, Paradox 3.0 is an extremely flexible and comprehensive fourth generation DBMS and software development tool. However, it does have some limitations discussed in chapter five. Once the program was selected, the design phase was finalized and construction was started.

IV. SYSTEM DESIGN

A. INTRODUCTION

The Diabetes Support System was designed to enable users with limited computer experience the freedom to use the system with the minimum amount of preparation. It provides physician, medical staff personnel and diabetic users with a decision support system that features the following integrated software applications:

1. The application provides an electronic logbook for recording insulin dosages/glucose readings, as well as several trend analysis functions.

2. A patient record selection that allows the medical staff to access patient records and specific medical background and diet information.

3. A nutrition application that contains a database containing FDA food charts and diabetic food exchange charts that can be accessed for planning menus and or determining the nutritional content (fats, proteins, carbohydrates, etc.), as well as calculating caloric content.

4. An exercise application containing a database for determining caloric expenditures for various aerobic exercise activities based. The caloric expenditures are based on age, weight and sex.

B. DESIGN OVERVIEW

The Diabetes Support System application was designed as a specific decision support system. It will provide information to structured and semi-structured queries in support of physicians, dieticians and diabetics, for the purpose of monitoring and controlling diabetes. It was designed as a comprehensive system that could consolidate decisions from the three major diabetes regulatory factors, exercise, nutrition and insulin/glucose diagnostic information into a single source, interactive software

application. The system was constructed for use on any IBM compatible personal computer running DOS 3.1 or higher, 640K of RAM and secondary storage of 1 megabyte or a hard disk drive to run the application.

The Diabetes Support System contains two applications that were developed independently: one for medical diagnostics and reference, and one that supports dietary and exercise decisions. This provides the users with the capability of installing and running either program as an independent stand-alone application or as a single entity. For the purpose of discussion in this paper, the application is described and examined as one program.

C. SYSTEM COMPONENTS

The Diabetes Support System consists of the three characteristic components that identify a decision support system: a database, model base and an interactive dialogue sub-system (Sprague and Carlson, 1982).

1. The Database

The database incorporates seven primary relations that provide reference, trend analysis and storage functions for the system's records. In addition, several auxiliary relations serve as validity-checking mechanisms that are activated through table lookup functions. The primary relations consist of:

1. Patient Records -- containing individual patient records (personal information, diet and medical history).

2. Logbook -- an electronic logbook containing individual patient glucose readings, insulin dosages, dates and remarks. The data for the glucose trend analysis graphs are extracted form this table.

3. Foodex -- contains food composition records for the diabetic food exchanges. This table is used as both a reference and as a lookup table for meal planning.

4. Foodcomp -- contains the USDA Home and Garden Bulletin 72. This contains over eight hundred food composition records, used as a reference source.

5. Mealrecs -- contains patient menu records.

6. Dictionary -- a reference dictionary that contains useful medical terminology.

7. Exercise -- contains information on caloric expenditures for specific body weights and exercise activities, used as a reference source.

8. Profiles -- contains information on a patient's individual menu profile.

9. Menudate -- contains the date the menu was prepared and lookup data from the Foodex relation.

2. The Model Base

Diabetes Support Systems's model base consists of graphical display models that support glucose trend analysis. The models were constructed using Paradox's internal graphics generator, and are supported by data contained in the Logbook relation. Access to the model base can be accomplished in one of two ways:

1. Ad hoc -- using Paradox's query-by-example feature. Ad hoc trend analysis is only available when operating directly under the supervision of the Paradox 3.0 DBMS.

2. Predefined queries that are embedded in the stand-alone application under trend analysis selections .

3. The Interactive User Dialogue

The application provides an interactive user dialogue through menu driven displays and on-line help functions. The menu structure uses Paradox style menu conventions. This menu structure was designed and constructed using the Paradox Personal Programmer. Help screen displays were installed by the builders. Help selections are available at each menu level to guide the user.

The menu structure controls the access to application's database and model base, and guides the user through the system. It also allows the user to select a variety of functions. The Appendix contains the complete menu hierarchy along with associated menu selections.

D. REPRESENTATIONS, OPERATIONS, MEMORY AIDS AND CONTROL MECHANISMS

As previously stated, the ROMC technique was applied to design the Diabetes Decision Support System. This section examines the application's organization and functions using ROMC conventions. The discussion will focus on the systems Main Menu structure and two of the more complex modules: Trend Analysis (accessed through Electronic Logbook), and Design Menus (accessed through Nutrition/Exercise). For a more comprehensive description of the entire system, refer to the user's manual in Appendix. The menu numbering is for clarification only. The convention used will allow the reader to identify where the selection is located in the menu hierarchy. The first digit refers to the main menu select, which are numbered from left to right for clarification purposes. The second digit is the menu level and the third digit, if present, is the menu selection numbered from left to right. An example would be 2.3.1, the first number (2) refers to the Main Menu selection (Patient Records) through which the selection is reached. The second digit (3) indicates the selection is at the third menu level and the third (1) digit refers to the first menu item (Update Patient) on that level.

1. The Main Menu

The main menu provides access to all of the Diabetes Support System's menu selections and associated forms, reports, graphs and functions. It allows the user to select one of six menu selections: (Figure 3)

1.1 Electronic Logbook

2.1 Patient Records

3.1 Reports

4.1 Nutrition/Exercise

5.1 Dictionary

6.1 Help

7.1 Leave

a. Representations -- Screen presentation of Main Menu selections.

b. Operations -- Each menu item provides access to the second-level menu selection items.

c. Memory Aids -- Menu selection descriptions for each item appear when the selection is highlighted. On-line help is also available.

d. Control Mechanisms -- The menu selections and Leave selection (exits program).

1.1 Electronic Logbook

Selecting Electronic Logbook from Main Menu provides access to second-level selections: (Figure 4)

1.2.1 Update Logbook

1.2.2 Trend Analysis

1.2.3 Help

a. Representations -- Screen presentation of Main Menu level menu selections.

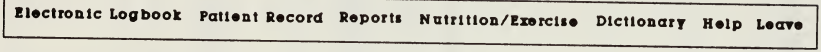

Figure 3 Main Menu Selections

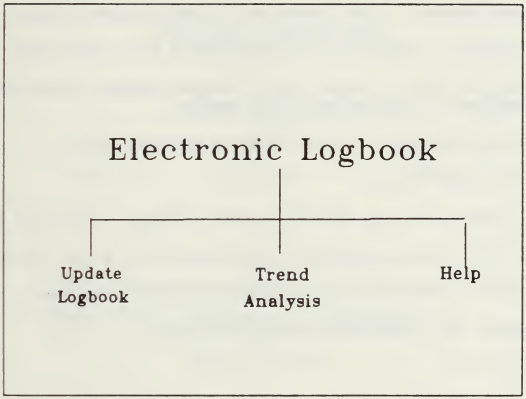

Figure 4 Electronic Logbook
Level Two

b. Operations -- Each menu item provides access to the second-level menu selection items.

c. Memory Aids -- Menu selection descriptions for each item appear when the selection is highlighted. On-line help is also available.

d. Control Mechanisms -- The menu selections and Leave selection (exits program).

1.2.2 Trend Analysis

Second-level menu selections that access third-level trend analysis selections.

a. Representations -- Screen presentation of second-level menu selections.

b. Operations -- Controls access to three third-level menu selection items.

c. Memory Aids -- A menu selection description appears when selection is highlighted. On-line help selection is available.

d. Control Mechanisms -- The ENTER key selects menu selection.

1.2.2 Trend Analysis

A second-level menu selection that allows the user to access the glucose logbook relation through a query that prompts the user for the patient's last and first name. The user is then provided access to the third-level menu selections that support trend analysis. The third-level selections include: (Figure 5)

1.3.1 By Day

1.3.2 By Meal

1.3.3 Help

a. Representations -- Screen presentation of second-level menu selections.

b. Operations -- Controls access to three third-level menu selection items.

c. Memory Aids -- A menu selection description appears when selection is highlighted. On-line help selection is available.

d. Control Mechanisms -- The ENTER key selects menu selection.

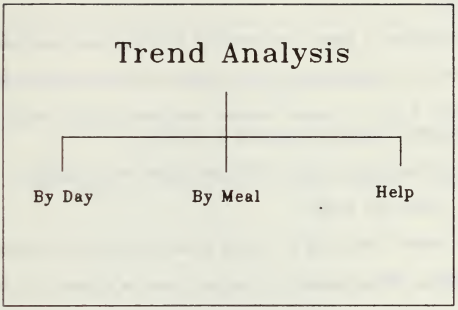

Figure 5 Electronic Logbook
Level Three

1.3.1 By Day

Third-level menu selection that gives access to fourth-level menu selections. (Figure 6)

1.4.1 3 Day Trend

1.4.2 7 Day trend

1.4.3 14 Day Trend

1.4.4 Help

a. Representations -- Screen presentation of third-level menu selections.

b. Operations -- Controls access to four fourth-level menu selection items.

c. Memory Aids -- A menu selection description appears when selection is highlighted. On-line help selection is available.

d. Control Mechanisms -- The ENTER key selects menu selection.

1.4.1 Three Day Trend

This selection will result in a graph of the last three day's glucose readings for trend analysis. When selected, the logbook relation is accessed and the last three days' glucose readings are selected based on the current computer internal clock date. The glucose readings consist of readings entered for the breakfast, lunch, dinner and night blood glucose tests. These are placed in an answer table. A graph is then constructed displaying a title indicating the number of days for the graph; in this case, "Glucose Logbook 3 Day Trend". The Y-axis displays the glucose range in mMdl. This axis is automatically scaled based on the highest value present in the sample. The X-axis displays the dates. A key is provided that is used to differentiate the glucose readings by meal. A blank screen is presented to the user until the graph is displayed, hiding the selection and background steps. (Figure 7)

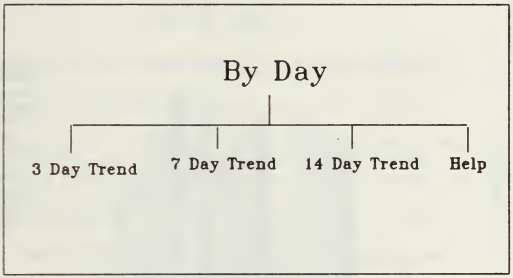

Figure 6 Electronic Logbook
Level Four

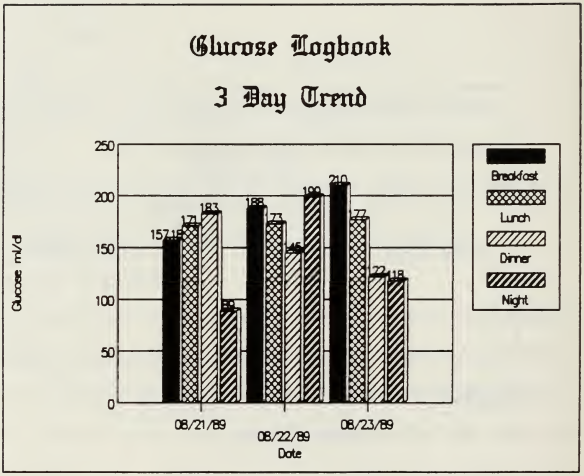

Figure 7 Three Day Trend Analysis

4.1 Nutrition/Exercise

A main menu selection item that provides access to the five second-level menu selection items: (Figure 8)

4.2.1 Nutrition

4.2.2 Exercise

4.2.3 Reports

4.2.4 Help

4.2.5 Leave

a. Representations -- Screen presentation of a Main Menu selection items.

b. Operations -- Selects menu item.

c. Memory Aids -- A menu selection description and on-line help is provided.

d. Control Mechanisms -- The ENTER key activates the menu selection.

4.2.1 Nutrition

A second-level menu selection item providing access to four third-level menu selection items: (Figure 9)

4.3.1 Food Exchanges

4.3.2 Meal Planning

4.3.3 USDA Food Values

4.3.4 Help

a. Representations -- Screen presentation of third-level menu selection items.

b. Operations -- Selects menu item.

c. Memory Aids -- A menu selection description and on-line help.

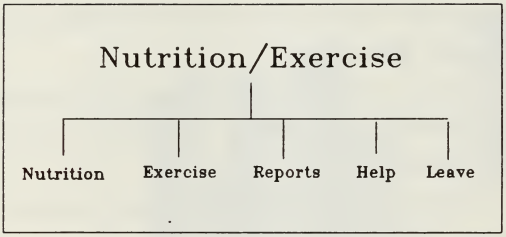

Figure 8 Nutrition/Exercise
Level Two

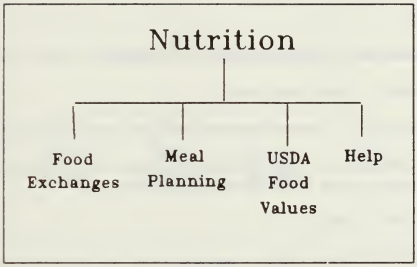

Figure 9 Nutrition/Exercise
Level Three

d. Control Mechanisms -- The ENTER key activates the menu selection. The ESC key returns the user to the Main Menu.

4.3.2 Meal Planning

A third-level menu selection item that provides access to four fourth-level menu selection items. (Figure 10)

4.4.4 Menu Design

4.4.5 View/Edit Menus

4.4.6 Delete Menus

4.4.7 Help

a. Representations -- Screen presentation of fourth-level menu selection items.

b. Operations -- Selects menu item.

c. Memory Aids -- A menu selection description and on-line help.

d. Control Mechanisms -- The ENTER key activates the menu selection. The ESC key returns the user to the second-menu level.

4.4.4 Menu Design

A fourth-level menu selection item that allows the user to access the MenuDate and MealRecs relations for the purpose of designing and storing personalized daily menus.

a. Representations -- A multi-table/multi-page screen presentation form that contains the following:

   1. A master form that is used to enter date and day to the MenuDate relation.

   2. One embedded form used to enter a patient's personal data and menu profile into the MenuDate relation.

   3. One embedded form used to enter food exchange data into the MealRecs relation.

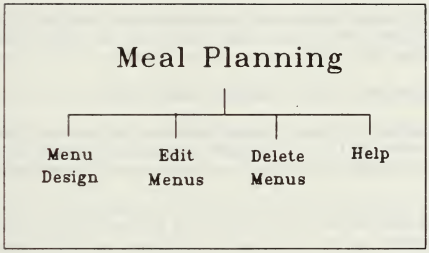

Figure 10 Nutrition/Exercise Level Four

b. Operations -- The primary function of this module is data entry. This is accomplished through the multi-table form. Data entry operations include:

1. A table lookup function used to enter data from the Profile relation into the MenuDate relation. This is activated when the cursor is placed on the SSN (Social Security Number) field.

2. A table lookup function used to enter data from the Foodex relation into the MealRecs relation. This is activated when the cursor is placed on the Food field.

3. A table lookup function used to select and enter the value for the Day field. This copies the selected day value from the auxiliary Days relation into the MenuDate Day field.

4. A table lookup function used to select and enter the value for the Meal field. This copies the selected Meal value from the Codes relation into the MealRecs Meal field.

5. Keyboard entry to the "Date" and "Units" fields.

c. Memory Aids -- A screen message located at the top of the form prompts the user to select the F2 key to complete the data entry process, ESC to cancel and CTRL-U to undo last change. It also includes specific instructions for entering data.

d. Control Mechanisms -- The master form has the following embedded control mechanisms:

1. The F2 key completes the data entry process and returns the user to the main menu.

2. The F3 and F4 keys allow the user to move the cursor from one embedded form to another, Up and Down respectively. This allows the user to activate the data entry function for the selected form.

3. The Tab and Arrow keys allow the user to move from field to field within the selected form.

4. The F1 and F2 Keys allow the user to activate table lookup functions. This is accomplished by placing the cursor on the following fields and pressing F1: SSN, Day, Meal and Food. The F2 key completes the table lookup data entry function.

5. The ESC key allows the user to cancel the editing session.

6. Validity checking is provided in two ways:

   a. Embedded validity check settings.

   b. Auxiliary table lookup functions described above.

7. The master form (MenuDate) enforces referential integrity by providing the following links:

   a. A one to many link from the MenuDate relation to the MealRecs relation. The relations are linked on the key fields SSN and Date.

   b. A one to many link from the Menudate relation to the Profiles relation. The tables are linked on the Key field SSN.

8. The PgUp/PgDn keys allow the user to move from one page to another.

9. Pressing CTRL-U will undo the last changes.

The forms and reports have been designed to aid the user in the input of data by having value range checks, lookup tables and default value entries. The value ranges will notify the user that a value entered is not in the range of possible values with a tone and will automatically go into edit mode until a value that is within range is entered. Lookup tables are provided to aid in the entry of data by displaying a data table with all the possible selections. The user highlights the desired selection and presses the F2 key to enter the data into the form. Default entries are provided to reduce the amount of information that is needed to be keyed in. The user is required only to place the cursor into the field that has this capability, i.e. a date field, and the current date in entered from the computer's clock when the cursor is moved from the field.

The next chapter will discuss the conclusions of the entire process.

V. DISCUSSION AND CONCLUSIONS

A. USES OF THE DIABETES SUPPORT SYSTEM

The Diabetes Support System has a number of advantages to offer both the health professionals and the diabetic. The major advantage of the system is it provides a central location for the vast amount of information needed by the diabetic and the medical center in an easily usable form. By centrally locating the information, the system could ideally be used as a teaching aid for the new diabetic. A significant amount of the information needed is provided. The system could also be used in the hospital or the clinic to get the patient comfortable with the daily routine of diabetes maintenance. This will build the patient's confidence more quickly and allows the physician or teaching nurse to monitor the patient's progress to determine when he is ready to be on his own. The menu structure is simple and can be used with limited computer experience. With use of this system the diabetic can start taking charge of his life sooner.

The Patient Data section can be used by the physician to provide background information on the patient to refresh his memory prior to seeing the patient. This would be beneficial in large or high volume clinics to improve the "personal" touch. It will provide essential information on medical history and diet needed for each visit. The Electronic Logbook can be used by both the physician and patient to monitor the patient's progress with glucose monitoring and insulin manipulation. By having printouts and graphs of the three months of glucose readings available, the physician

can easily identify trends without the need to leaf through pages of a standard hand-written logbook. The patient is able to use these features to monitor daily trends and make needed adjustments to maintain control. The key to diabetes is control of the blood sugars and being able to identify the need for changes enables control to be maintained.

Meal plans and exercise plans can be reviewed if control has not been good. The Nutrition section can also be used by the dietician and the patient for meal planning and discussions about food exchanges and caloric intake. With this system the patient has the ability to plan and printout daily menus to aid in calorie intake and nutrition requirements. This will allow a better exchange of information for an essential element in diabetes control. Menus, planned by the patient, can be reviewed and suggestions or alterations can be made easily.

The Dictionary section, although of little use to the physician, is of great use to the patient in answering questions and clarifying terminology used by the physician. At this time, no other diabetes data management system is available that has all the features of this system.

Another major advantage is the flexibility of the system. Most systems on the market are very structured and allow only certain information to be input. With the use of the remarks sections the physician, dietician or the patient has an area where specific comments and amplifying information can be stored. This eliminates the need for the patient to remember codes to explain various glucose readings. The physician also has more information available about the patient's medical history; such as other diseases and types of medication the patient is taking to avoid conflicting treatments.

If the system is run under Paradox the query-by-example feature is available for ad hoc queries. This will allow for almost unlimited flexibility in information access and could be used in clinical research. This may be further enhanced when Structured Query Language (SQL) is added by the end of the year.

The system also has the capability of being used as two stand-alone applications. The system can be used as a total Diabetes Support System with all its features or the Nutrition/Exercise section can be used separately. This will allow the dietician to maintain only the information pertaining to diet on another computer or only access the portion needed. This feature will give a Type II diabetic a stand-alone Nutrition/Exercise section that would be of most use to him.

B. PARADOX 3.0 PROBLEM AREAS AND ADVANTAGES

1. The Advantages

The advantages of Paradox 3.0 far outweighed the disadvantages. As previously stated in chapter III, the Paradox system was chosen because it fulfilled all of the requirements for a relational data-base system that supported a programming language and had graphic capabilities.

The major advantage of using a fourth generation language (4GL) is that it provides the user with the ability to develop a complex and sophisticated data management system without large amounts of programming experience. The power of Paradox facilitated prototyping by allowing the basic system to be developed quickly. This enabled the prototype to go through three iterations in less than four months including a three to four week learning phase. This was further enhanced by the use of the PAL programming language. This was used to write code to perform specific

functions and add enhancements to the final product. The combination added greater flexibility and allowed a more comprehensive application to be developed.

Another advantage of Paradox 3.0 is that once a system application has been developed it can be run as a stand-alone system, with the soon-to-be-released Run-Time program. This will allow the system to be run without the underlying Paradox program.

2. Problem Areas

Several problems were identified with the use of Paradox 3.0. First was the initial learning curve that is encountered when dealing with any unfamiliar software product. As with all new and sophisticated software, there is a large learning curve to overcome. This was expected to some degree.

A second problem, related to the first, is that Paradox actually consists primarily of three main programs, the DBMS, the Personal Programmer and the PAL programming Language. Although related and similar, each necessitates a separate learning curve. The PAL programming language was structured somewhat like Pascal but it contained a number of command abbreviations that were not well-documented.

A third problem that was encountered was the quality of the vendors' support documentation and reference manuals. Although comprehensive in nature, they were poorly organized and lacked a complete glossary of error messages. This increased the difficulty of debugging. A library of sample PAL applications would be most welcome also. At the time development was started, only information from Borland was available.

The database management system was easy to learn and use, but had a large number of features that took time to master. The DBMS was used to build the database tables, forms and reports. The capabilities of the program were excellent; the query-by-example added great flexibility. The personal programmer was used to build the menu structure and generate the basic code. There were a number of problems encountered with this code. The major problem involved errors developing after repeatedly recompiling the code after frequent changes. This proved to be due, in part, to an existing problem that the Borland company has been unable to correct.

In summary, some of the problems were due to the use of a newly released version shortly after a major revision. The problems encountered, however, were not major and considering the size and complexity of the Paradox system were insignificant.

C. THE DIABETES SUPPORT SYSTEM CONCLUSIONS

The Diabetes Support System (DSS) proved to be a much larger project than was first envisioned, as is typical of most systems development projects. However, a comprehensive application was developed in 4 months on a part-time basis.

With the major backlogs of software awaiting development in most organizations, a 4GL will allow the users to develop some systems themselves and free the programming department to address problems in other areas.

The Diabetes Support System, as proof of concept, shows that a comprehensive system can be developed in minimum time using fourth generation technology. It also shows that decision support can be applied to diabetes control and maintenance, enabling better treatment and comprehensive care.

The Veterans Administration and the military medical systems are overtaxed and in need of automation. A Diabetes Support System that can be used as a teaching aid and as a management tool will reduce much of the administrative work load on the staff. This application allows for easy maintenance of patient records as well as specific trend analysis, meal planning and exercise programs. By having much of the data needed to manage diabetes in one location, valuable time can be saved for more critical needs. In high volume clinics, the physician does not have the time to spend with each patient. By being able to quickly access the patient's history and any personal data, the physician can at least give the impression of personal involvement one sees in small clinics. This will reinforce the patient's feeling that someone cares how they are doing, encouraging him to stay on the strict regime.

D. THE FUTURE

Some of the reports and graphs were reviewed by endocrinologists and some enhancements were suggested. This entailed the addition of statistical data, such as mean and standard deviations. It was also suggested that a 30 day glucose scatter graph be added to the selection. These features could most likely be incorporated into the system without major changes.

The Diabetes Support System is at a point where a comprehensive testing phase is the next step. After corrective maintenance for any errors has been finished, the system should be beta tested in a clinical situation or a endocrinologist's office. This will allow the system to be evaluated under normal operating conditions. With the results from the beta testing, the final enhancements or changes can be added to the system. At that time the final versions of the documentation can be completed.

APPENDIX

USERS MANUAL

A. PROGRAM OVERVIEW

The Diabetes Support System (DSS) is designed to enable both the physician and the diabetic to better manage diabetes. The physician is able to use the DDS system to maintain patient records and as an teaching aid for diabetics. The diabetic can use the system, in the home, to help with blood sugar control and monitoring. The DSS strategy is to allow the user a unified system that is both flexible in its breadth and yet simple to use. By having all the information located in one place, the user can easily obtain the needed information to maintain a proper glucose balance. A menu-type system was used to reduce the required learning time.

The menu numbering is for clarification only. The convention used will allow the reader to identify where the selection is located in the menu hierarchy. The first number refers to the main menu select, which are numbered from left to right for clarification purposes. The second number is the menu level and the third number, if present, is the menu selection numbered from left to right. An example would be 2.3.1, the first number (2) refers to the Main Menu selection (Patient Records) through which the selection is reached. The second number (3) indicates the selection is at the third menu level and the third (1) number refers to the first menu item (Update Patient) on that level.

Main Menu

The Main Menu includes 7 selections consisting of: (Figure A1)

a. Electronic Logbook

The Electronic Logbook maintains a listing of glucose readings and insulin dosages by calendar date. This allows easy trend analysis so insulin dosages, exercise and food intake be altered to maintain blood glucose levels within desired levels.

b. Patient Records

The Patient Records selection contains a database containing the patient's background information to include: address, medical history and diet.

c. Reports

The Report section provides copies of: Patient Records, Patient Glucose Logbook, a Patient Listing report, and Trend Analysis graphs to the printer.

d. Nutrition/Exercise

This selection provides two sub-sections, one for food related information and the other for exercise. The nutrition section contains a comprehensive database of foods and diabetic food exchanges. It allows the user to build weekly menus, determine nutritional values of foods and caloric intake to better enable the user to monitor food intake. The exercise selection allows the user to access a database with exercise information on caloric expenditure for various exercises. This allows the diabetic to use exercise to aid in maintaining glucose levels.

e. Dictionary

The dictionary provides a readily accessible list of diabetic and medical terms plus definitions for the user to answer frequently asked questions.

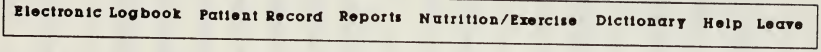

Figure A1 Main Menu Selections

f. Help

At each menu level there is a Help menu to provide on-line help to the user.

g. Leave

The leave selection is used to quit the DSS program and return to the DOS level.

B. CONTROL MECHANISMS

1. Function Keys

This section provides a description of the various keys used to control the movement of the cursor and initiate/complete various functions throughout the application.

1. ENTER -- used to activate menu selections or functions.
2. ESC -- returns you to the previous menu, with one exception. When performing an edit or data entry function, the ESC key can be used to cancel those functions.
3. TAB -- used to move the cursor horizontally from field to field.
4. The Right/Left Arrow keys -- same as the Tab key.
5. The Up/Dn Arrow keys -- used to move the cursor up or down.
6. F1/F2 -- used to activate a table lookup function. This is accomplished by placing the cursor on the designated field and pressing the F1 key. This will place the lookup table on the screen. Move the cursor to the record that contains the data that you wish to copy. Then Press the F2 key; this will complete the function.
7. F2 only -- used to complete editing or data entry function. This will return you to the Main Menu.

8. F3/F4 keys -- used to move the cursor from one embedded form to another within a multi-table form.

9. F9 -- used to activate the editing mode.

10. Pressing CTRL-U will undo the last changes that were made during an edit or data entry session.

11. Pressing CTRL-BREAK will stop a report from being printed.

2. Selecting Menu Items

To choose a menu selection, either

-- type the first letter of the selection, or

-- use the arrow keys to highlight the selection and press the ENTER key.

To cancel the selection or move to the next higher menu level press the ESC key.

C. MENU SELECTION DETAILS

1. Electronic Logbook Menu Structure

The Electronic Logbook is the master record of glucose readings. The logbook is indexed on the patient's social security number (SSN) and an individual's file is accessed by the patient's name. The glucose readings are further indexed by date.

The second level sub-menu of the Electronic Logbook consists of three selections which allow the user to update and analyze glucose information and obtain help information from the help menu. The sub-menu consists of: (Figure A2)

1.2.1 Update Logbook

1.2.2 Trend Analysis

1.2.3 Help

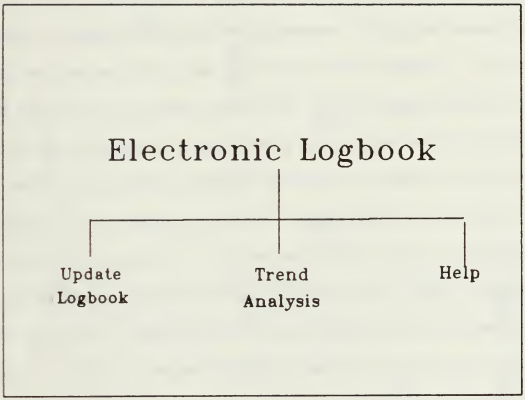

Figure A2 Electronic Logbook
Level Two

a. Level Two Structure

1.2.1 Update Logbook

This selection allows the user to select an individual's glucose logbook. The user is queried to enter the patient's last name and then for the patient's first name. The user will now see a multi-view table consisting, in the top half, the patient's name, Social Security Number, date of next visit and date of last visit. In the bottom half of the screen is a table, in tabular form, consisting of the date, insulin dosages, glucose readings and a remarks section. The insulin dosages are grouped by time of day i.e. breakfast, lunch dinner, dinner and night time with the types and amounts of insulin (regular or NPH). The glucose readings are also broken down by time of day in the same manner as the insulin dosages. A remarks section is provided to allow the user to indicate reasons for deviations or exceptions to either insulin dosages or high or low glucose values. The glucose logbook can be updated using normal editing keys such as delete and backspace. Moving from field to field is accomplished by either the arrow keys or more easily with the ENTER key. The logbook is keyed on the date and are listed in order of date. The Page Up and Page Down keys are used to move vertically through the logbook records to find, update or review a specific date. (Figure A3)

1.2.2 Trend Analysis

The Trend Analysis selection first queries for the patient's name to select the appropriate records. This leads to a third level sub-menu: (Figure A4)

1.3.1 By Day

1.3.2 By Meal

Patient's Name: Sample B. Data
SSN: 123-45-6780

Last Visit: January 1, 1989
Next Visit: April 1, 1989

Date: 16-Aug-89	BRK	LUN	DIN	NITE	REMARKS:
	NPH	NPH	NPH	NPH	
	10.5		11.5		
	GLUCOSE	GLUCOSE	GLUCOSE	GLUCOSE	
	98.0	154.0	184.0	156.0	
	REG	REG	REG	REG	
	8.0		12.0		

Figure A3 Update Logbook

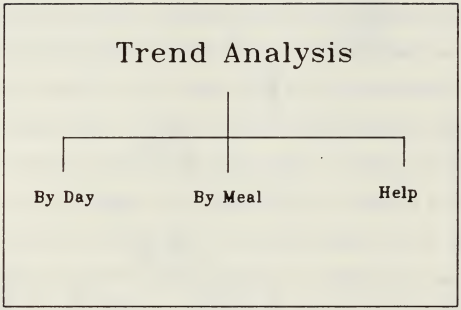

Figure A4 Electronic Logbook
Level Three

1.3.3 Help

b. Level Three Structure

1.3.1 By Day

This selection allows the user to select trend analysis of a previously selected patient glucose logbook. The trend will be based on a selected number of days of glucose readings. The day selection leads to a fourth level sub-menu consisting of: (Figure A5)

1.4.1 3 Day Trend

1.4.2 7 Day Trend

1.4.3 14 Day Trend

1.4.4 Help

c. Level Four Structure

1.4.1 3 Day Trend

This selection will present, from the patient's logbook, the last three days glucose readings in a graphic form. This will allow trend analysis. (Figure A6)

1.4.2 7 Day Trend

This selection will present from the patient's logbook, the last seven days glucose readings in a graphic form. This will allow trend analysis.

1.4.3 14 Day Trend

This selection will present from the patient's logbook, the last fourteen days glucose readings in a graphic form. This will allow trend analysis.

1.4.4 Help

The Help selection provide on-line help to the user.

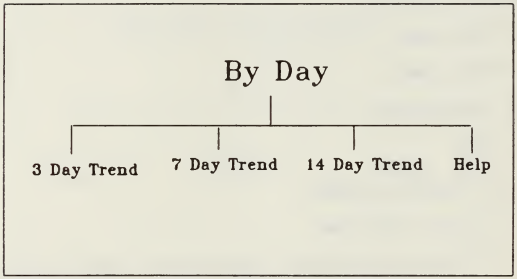

Figure A5 Electronic Logbook
Level Four

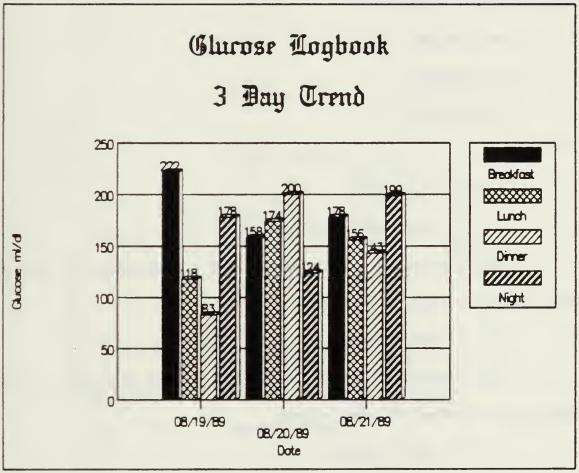

Figure A6 Three Day Trend Analysis

d. Level Three Structure

1.3.2 By Meal

This selection allows the user to select trend analysis of a previously selected patient glucose logbook. The trend will be based on a selected meal for a number of days of glucose readings. The meal selection leads to a fourth level sub-menu consisting of: (Figure A7)

1.4.1 3 Day Breakfast

1.4.2 7 Day Breakfast

1.4.3 14 Day Breakfast

1.4.4 Help

e. Level Four Structure

1.4.1 3 Day Breakfast (Figure A8)

This selection will present the user with a graph of the last three days' breakfast glucose readings for trend analysis.

1.4.2 7 Day Breakfast

This selection will present the user with a graph of the last seven days breakfast glucose readings for trend analysis.

1.4.3 14 Day Breakfast

This selection will present the user with a graph of the last fourteen days breakfast glucose readings for trend analysis.

1.4.4 Help

The Help selection provide on-line help to the user.

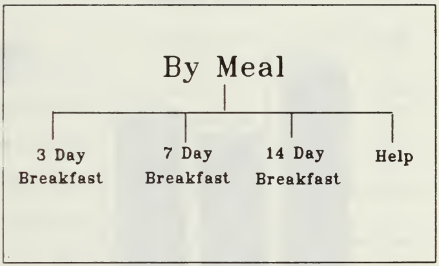

Figure A7 Electronic Logbook Level Four

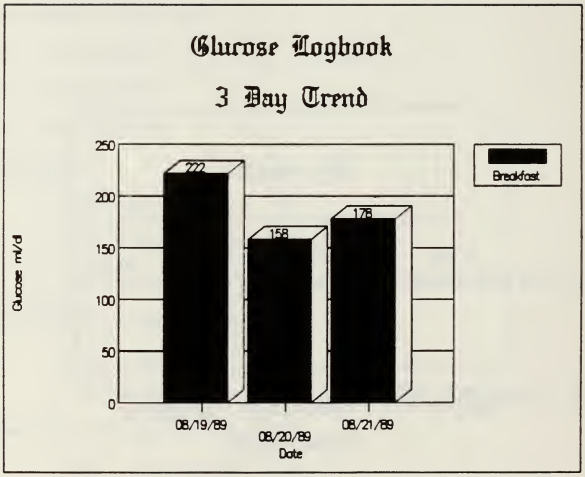

Figure A8 Three Day Breakfast

Other meal selections will be added for lunch, dinner and night when the application is readied for beta testing.

2. Patient Records Menu Structure

The Patient Records selection allows the user to view, update, add or delete patient records. Moving between the record sub-sections can be accomplished by using the F4 key as in the Electronic Logbook section. The second level sub-menu consists of: (Figure A9)

2.2.1 Update Records

2.2.2 Delete Records

2.2.3 Patient Listing

2.2.4 Help

a. Level Two Structure

2.2.1 Update Records

This selection allows the user to view, update and enter new records. When the user selects this menu item a query will ask for the last and first name of the patient record to select. The user will then be presented with a multi-record form containing the patient's background. The Patient Records record is divided into three sections: background information, medical history and diet information. The background information consists of the patient's name, address, telephone number, last and next visit.

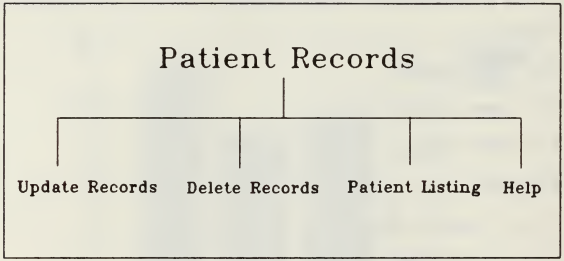

Figure A9 Patient Records Level Two

Medical History section holds a summary of the patient's medical background. This has valuable information about the patient's diabetes and other diseases for which the individual may be under treatment. It also contains critical information on medications to avoid conflicting treatments. Another essential part of the medical section is the remarks section. This allows the physician to add information pertinent to this specific patient, adding flexibility to the entire system.

The last section holds information on patient's diet, with important details about caloric intake and diet restrictions. Again, a remarks section is available to add patient specific flexibility.

This selection also allows the user to add a patient to the database. The user will be presented with a blank multi-record form. The user will then fill in the background data for a new patient. The user can enter data, ESC to quit without saving data or Undo what has been entered. To move from field to field the ENTER key is used. After the data has been entered the user press F2 to save the new record to the database. For a description of the form see Individual Record below. (Figure A10)

Patient Record Detail

If the Update Logbook selection is chosen the following selections are provided:

Individual Record

This selection queries the user for both the last and the first name of the desired record. The name must be capitalized in order to find the correct record.

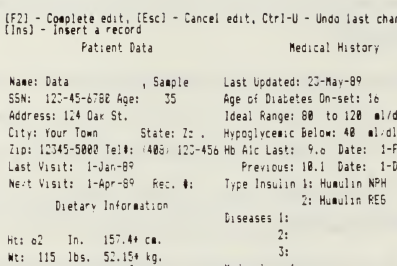

Figure A10 Patient Record

After the name has been entered a master patient data form will appear. This form will consist of three sections: a Patient data, Medical History and a Diet Information.

The Patient Records section contains the patient's name: last name, and first name. Next is the Social Security Number; this is the key field and is a unique number for each patient. This is followed by the patient's age and address. The Zip Code can be entered as a 5 digit number or as the Zip+4 number. The Last Visit and Next Visit are dates used for tracking quarterly clinic visits. The Last Updated field allows the physician to determine how recent the information is for each patient. The birthday field is an information field. The height and weight fields are entered in inches and pounds and automatically convert these to metric values and displays both U.S. and metric values.

The Medical History section comprises information on the medical background of the patient. The first entry is Age of Onset, to indicate how long the patient has had diabetes. This information is important in order to determine the types of medical problems that might exist or develop. The range and hypoglycemic provide information on the normal glucose range and when to expect hypoglycemic reactions. The last two hemoglobin A1c readings are provided to remind the physician the amount of control over the last 6 months. The types of insulin used is provided in case an insulin reaction occurs. Medical information about three most significant diseases and medications are provided to enable the physician to better determine which medications are appropriate. A remarks section is provided for the physician to add any special comments to the patient's medical information.

The diet section contains a summary of the patient's diet regimen. The daily caloric intake is provided along with whether the patient is on a fat or sodium restrictive diet. The patient's cholesterol is broken into both high and low density cholesterol, so the physician can monitor it. A remarks section is added for amplifying information.

2.2.2 Delete Records

Delete Patient allows the user to delete a patient's records form the database. The user is queried for the patient's last and first name to select the patient's record for deletion. This selection must be used with caution because the records are permanently lost and can not be recovered.

2.2.3 Patient Listing

Patient Listing provides a listing of all patients in the database. It contains the patient's names, social security number, age, date of last visit and date of next visit.

2.2.4 Help Help provides on-line help to the user.

3. Reports

The Reports section provides a means of obtaining a printed copy of the patient records and the glucose logbook. It consists of a second level sub-menu containing: (Figure A11)

3.2.1 Patient Records

3.2.2 Patient Listing

3.2.3 Patient Logbook

3.2.4 Trend Analysis

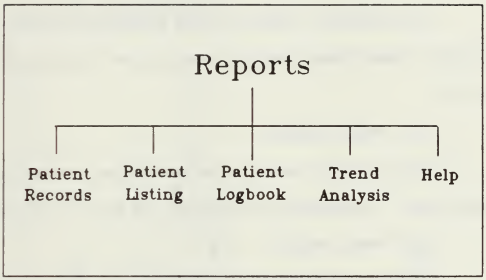

Figure A11 Reports Level Two

3.2.5 Help

a. Level Two Structure

3.2.1 Patient Records

The user will be prompted for the patient's last and first name to select the proper record. A printout of the patient record will be sent to the printer. It will consist of the information described in the Patient Records section. (Figure A12)

3.2.2 Patient Listing

This will provide a listing of all the patients in the database. It consists of the patient's Social Security Number, name, age, last visit and next clinic visit. (Figure A13)

3.2.3 Patient Logbook

The user will be queried for the patient's last and first name to select the proper records. The patient's glucose logbook will be sent to the printer.

3.2.4 Trend Analysis

The user is prompted for the patient's name to select the correct patient glucose logbook. This selection leads to a sub-menu containing the selections by day and by meal. These in turn lead to sub-menus in order to print the various trend graphs.

b. Level Three Structure

Trend Analysis has a level three menu consisting of: (Figure 14)

3.3.1 By Day

3.3.2 By Meal

3.3.4 Help

August 23, 1989 Patient Background Information Page 1

Patient Data

SSN: 123-45-6780
Last Name: Data
First Name: Sample
MI: B.
Age: 35
Address: 124 Oak St.
City: Your Town
State: Zz
Zip: 12345-5000
Last Visit: 1/01/89
Next Visit: 4/01/89
Phone: (408) 123-4567
Birthday: 1/01/55

Medical History

Last Updated: May 23, 1989
Age of Onset: 16
Ideal Glucose Range: 80 to 120 dl/ml
Hypoglycemic below: 40
Last Hb A1c: 9.6 Date: February 1, 1989
Previous Hb A1c: 10.1 Date: December 1, 1989
Type Insulin 1: Humulin NPH
Humulin REG
Diseases 1:
2:
3:
Medications 1:
2:
3:
Remarks:

Diet Information

Height: 62.0 In. cm.
Weight: 115.0 Lb. kg.
Daily Calory Intake: 1500 cal.
Low Sodium Diet: Y
Low Fat Diet: Y
Cholesterol LDL: 35 HDL: 137
Remarks:

Figure A12 Patient Records

August 23, 1989 Patient Listing Page 1

SSN	Last Name	First Name	MI	Age	City	State	Last Visit	Next Visit	Phone
123-45-6788	Data	Sample	B	35	Your Town	Zz	1/01/89	4/01/89	(408) 123-4567
123-45-6789	Data	SampleA	A	21	Another Town	Qq	6/06/89	9/06/89	123-5555

Figure A13 Patient Listing

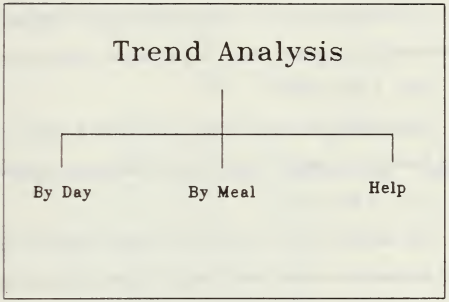

Figure A14 Reports Level Three

The By Day selection consists of a menu consisting of: (Figure 15)

3.4.1 3 Day Trend

3.4.2 7 Day Trend

3.4.3 14 Day Trend

3.4.4 Help

c. Level Four Structure

3.4.1 3 Day Trend

This selection will print a report of the patient's logbook, the last three days' glucose readings in a graphic form. This will allow trend analysis. (Figure A16)

3.4.2 7 Day Trend

This selection will print a report of the patient's logbook, the last seven days glucose readings in a graphic form. This will allow trend analysis.

3.4.3 14 Day Trend

This selection will print a report of the patient's logbook, the last fourteen days glucose readings in a graphic form. This will allow trend analysis.

3.4.4 Help

The Help selection provides on-line help to the user.

3.3.2 By Meal (Figure A17)

This selection will allow the user to select trend analysis of a previously selected patient glucose logbook. The trend will be based on a selected meal for a number of days of glucose readings. The meal selection leads to a fourth level sub-menu consisting of:

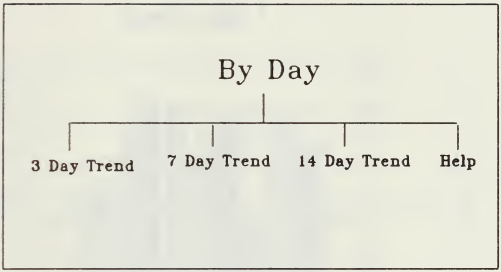

Figure A15 Reports Level Four

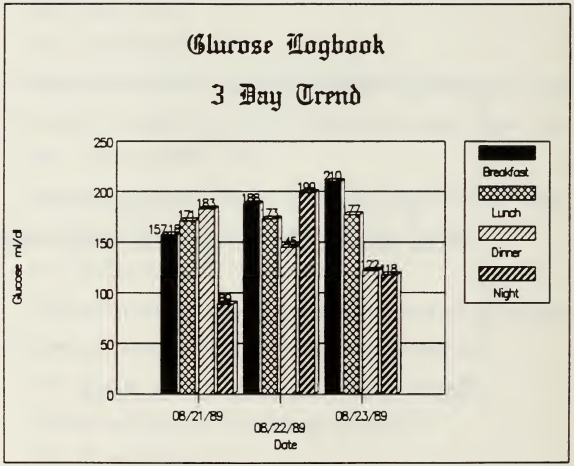

Figure A16 Three Day Trend Analysis

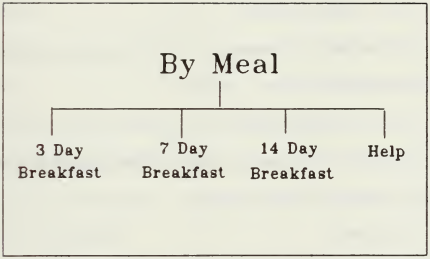

Figure A17 Reports Level Four

1.4.1 3 Day Breakfast

1.4.2 7 Day Breakfast

1.4.3 14 Day Breakfast

1.4.4 Help

d. Level Four Structure

1.4.1 3 Day Breakfast

This selection will present the user with a graph of the last three days' breakfast glucose readings for trend analysis.

1.4.2 7 Day Breakfast

This selection will present the user with a graph of the last seven days' breakfast glucose readings for trend analysis.

1.4.3 14 Day Breakfast

This selection will present the user with a graph of the last fourteen days' breakfast glucose readings for trend analysis.

1.4.4 Help

The Help selection provide on-line help to the user.

Other meal selections will be added for lunch, dinner and night when the application is readied for beta testing.

4. Nutrition/Exercise

The Nutrition/Exercise selection provides access to dietary planning, exercise and nutritional information. By selecting, a variety of decision support functions can be performed to include:

1. Viewing, editing, data entry and printing food exchange charts.
2. Designing, editing, deleting and printing personal daily menu plans.
3. Viewing, editing and printing USDA food composition values.
4. Viewing, editing and printing an exercise activity chart.
5. Viewing on-line help screens that are available at each menu level.

This section outlines the Nutrition/Exercise menu structure. Selecting Nutrition/Exercise causes the screen to display two second-level menu selections and three menu functions: (Figure A18)

4.2.1 Nutrition

4.2.2 Exercise

4.2.3 Reports

4.2.4 Help (on-line help available at each menu level.)

4.2.5 Leave (returns to the Main Menu.)

a. Level Two Structure

4.2.1 Nutrition

The Nutrition selection provides access to the food exchange charts, meal planning functions and USDA Home and Garden Bulletin #72 through the following sub-menu: (Figure A19)

4.3.1 Food Exchanges

4.3.2 Meal Planning

4.3.3 USDA Food Values

4.3.4 Help

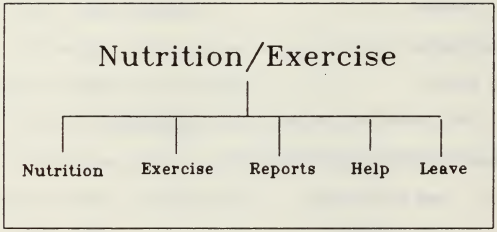

Figure A18 Nutrition/Exercise
Level Two

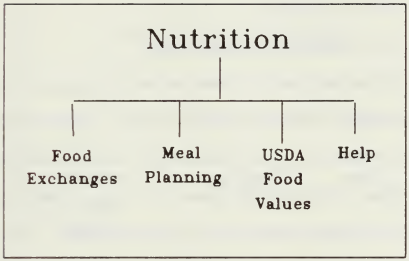

Figure A19 Nutrition/Exercise
Level Three

b. Level Three Structure

4.3.1 Food Exchanges

The Food Exchanges selection provides access to the food exchange database through a sub-menu that consists of: (Figure A20)

4.4.1 View/Edit Exchange Charts

4.4.2 DataEntry

4.4.3 Help

c. Level Four Structure

4.4.1 View/Edit Exchange Charts

The user will queried to enter the food exchange to be viewed or edited. Select and press ENTER. The screen will then display a form that contains foods listed in the selected exchange. The Up/Dn arrow keys are used to scroll through the form one record at a time. The PgUp/PgDn keys scroll by page. The TAB and Right/Left arrow keys move the cursor from field to field, horizontally. F2 will complete the session, ESC cancels the session and CTRL-U will undo the last changes made. (Figure A21)

4.4.2 DataEntry

This selection allows new records to be entered into the Food Exchange database. When selected, a blank multi-record form will appear on the screen. Data must be entered in each field. The cursor in moved through the form by using the same keys as described above.

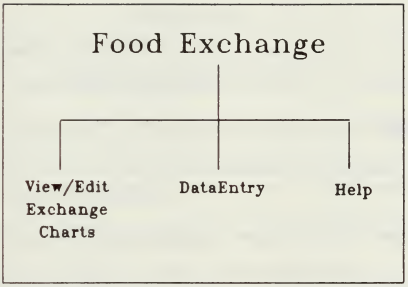

Figure A20 Nutrition/Exercise Level Four

[F2] - Data entry completed, Esc - Cancel data entry, Ctrl-U - Undo last change

FOOD EXCHANGE CHART

Food	Ex	Units	Meas	Cals	P-Ex	M-E	B-Ex	F-Ex	V-Ex	O-Ex	Chol	Sod
CANTALOUPE	F	.25	melon	45	0.0	0.0	0.0	1.0	0.0	0.0	0	0
CARROTS	V	.5	cup	25	0.0	0.0	0.0	0.0	0.0	0.0	0	0
CASHEWS,Whole	O	6	each	45	0.0	0.0	0.0	0.0	0.0	1.0	0	0
CATSUP	E	2	tsp	20	0.0	0.0	0.0	0.0	0.0	0.0	0	0
CAULIFLOWER	V	.5	cup	25	0.0	0.0	0.0	0.0	0.0	0.0	0	0
CELERY STALKS	V	.5	cup	25	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Figure A21 View/Edit Exchange Charts

d. Level Three Structure

4.3.2 Meal Planning

This selection allows the user to plan, edit or delete daily menus through a sub-menu that contains: (Figure A22)

4.4.4 Menu Design

4.4.5 Edit Menus

4.4.6 Delete Menus

4.4.7 Help

e. Level Four Structure

4.4.4 Menu Design (Figure A23)

This selection allows the user to design personal daily menus. Selecting this item provides access to the MenuDate, Profiles and MealRecs. A multi-table screen form that contains the following:

1. A master form that is used to enter date and day to the MenuDate relation.
2. One embedded form used to enter a patient's personal-data and menu profile into the MenuDate relation.
3. One embedded form used to enter food exchange data into the MealRecs relation.

The primary function of this module is data entry. This is accomplished through the multi-table/multi-page form. Data entry operations include:

1. A table lookup function, used to enter data from the Profile relation into the MenuDate relation. This is activated when the cursor is placed on the SSN field and F1 is pressed. A Profile relation will be displayed on the screen. Move the cursor to the SSN of the patient whose menu is being designed and press F2. This will perform the table lookup function and enter all of the appropriate data from the Profile relation into the embedded Profile.

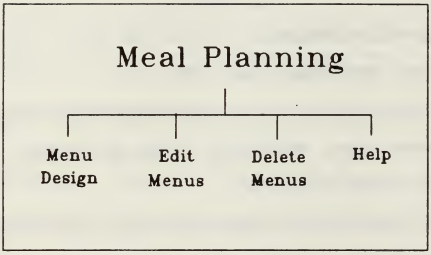

Figure A22 Nutrition/Exercise Level Four

[F2] - Data entry completed, Esc - Cancel data entry, Ctrl-U - Undo last change

PgUp/PgDn selects page. For Table Lookup - F1 activates/F2 completes data entry.

Instructions: Move cursor to SSN. Press F1. Select record from lookup table and press F2. Move to Date and enter or just press the spacebar for todays date. Move to Day a perform table lookup. Press PgDn to enter foods.

MENU PLANNING INFORMATION

SSN: 129-46-1802
Menu Profile for Steve Albert

Breakfast:	2M,1.5F,1B
Morning Snack:	1F
Lunch:	1P,1B,1O
Afternoon Snack:	1B,1V
Dinner:	1B,1M,1V,2P
Evening Snack:	1F
Optional:	1B,1M

TCals:	1750	TChol:	600	TSod:	1200

Menu preparation date: Monday 31-Jul-89

CODES

P - Protein
M - Milk
B - Bread/Starch
F - Fruit
V - Vegetable
O - Oil/Fat
E - Mixed/Free Foods

A - Breakfast
B - Morning Snack
C - Lunch
D - Afternoon Snack
E - Dinner
F - Evening Snack
G - Optional

Figure A23 Menu Design

2. A table lookup function used to enter data from the Foodex relation into the MealRecs relation. This is activated when the cursor is placed on the Food field.

3. A table lookup function used to select and enter the value for the Day field. This copies the selected day value from the Auxiliary Days relation into the MenuDate Day field.

4. A table lookup function used to select and enter the value for the Meal field. This copies the selected Meal value from the Codes relation into the MealRecs Meal field.

5. Keyboard entry is required for the Date and Units fields. A screen message located at the top of the form prompts the user to select the F2 key to complete the data entry process, ESC to cancel or Ctrl-U to undue the last changes. Cursor movement is controlled as previously described. However, some additional capabilities are provided by the following keys:

The F3 and F4 keys allow the user to move the cursor from one embedded form to another. This allows the user to activate the data entry function for the selected form. Validity checking is provided in two ways: first, through embedded validity check settings and second through the auxiliary table lookup functions described in the Operations section above. The PgUp and PgDn keys allow the user to change from one page to another.

The master form (MenuDate) enforces referential integrity by providing the following links:

1. A one-to-many relationship from the MenuDate relation to the MealRecs relation. The relations are linked on the key fields SSN and Date.

2. A one-to-many relationship from the Menudate relation to the Profiles relation. The tables are linked on the Key field SSN.

4.4.5 Edit Menus

The Edit Menus selection allows selecting and editing of a patient's menu records. A prompt will ask for the patient's Social Security Number and the date that

the menu was prepared. The screen will display a multi-table form exactly like the one that is used for Menu Design. Use the cursor keys (previously described) to move to the field(s) that you wish to edit and enter the new values. Press F2 to complete the session.

4.4.6 Delete Menus

This selection allows deletion of menus. This is accomplished through a prompt that queries for the patient's SSN and the Date of the record(s) to be deleted.

f. Level Three Structure

4.3.3 USDA Food Values

This selection gives access to the USDA Home and Garden Bulletin #72. Two sub-menu selections are provided at this level: (Figure A24)

4.4.8 View USDA Bulletin

4.4.9 Help

g. Level Four Structure

4.4.8 View USDA Bulletin

This function will allows the display and viewing of the entire USDA Home and Garden Bulletin #72. The screen presentation is in tabular form. The TAB and arrow keys are used to move from field to field. The PgUp/PgDn keys will scroll through the table a page at a time. Press F2 to return to the Main Menu.

h. Level Two Structure

4.2.2 Exercise

The Exercise selection allows the access to exercise planning information through the following sub-menu: (Figure A25)

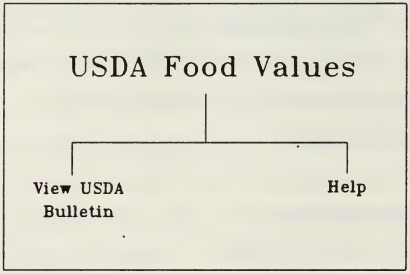

Figure A24 Nutrition/Exercise Level Four

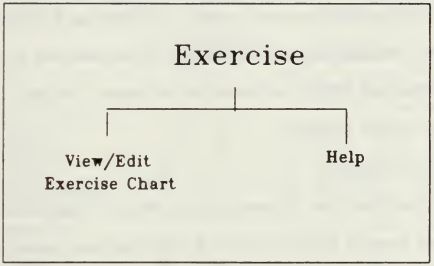

Figure A25 Nutrition/Exercise
Level Three

4.3.5 View/Edit Exercise Chart

4.3.6 Help

i. Level Three Structure

4.3.5 View/Edit Exercise Chart

This selection will allows the user to view or edit the Exercise Chart. The screen displays a form that contains exercise activities and caloric expenditure per hour based on body weight. The Up/Down arrow keys will scroll through the records one at a time. PgUp/PgDn keys scroll by page. The TAB and Right/Left arrow keys move the cursor from field to field, horizontally. F2 will complete the session, ESC cancels the session and CTRL-U will undo the last changes. (Figure A26)

j. Level Two Structure

4.2.3 Reports

Allows the Food Exchange Charts, Menus, USDA Food Composition Reports and the Exercise Chart to be printed. This selection provides access seven different reports. The source data for these reports includes:

1. Food Exchange Reports -- American Diabetes, Association 1988, McMahon and Travis 1984, and Netzer 1988.
2. USDA Food Value Reports -- USDA Home and Garden Bulletin Number 72, 1981.

These reports are accessed through the following sub-menu selections: (Figure A27)

4.3.7 Food Exchange Charts

4.3.8 All Charts

[F2] - Data entry completed, Esc - Cancel data entry, Ctrl-U - Undo last change

EXERCISE CHART
* Calories Burned Per Hour for Selected Activities *

Activity	110lbs	130lbs	150lbs	170lbs	190lbs	215lbs
BACKPACKING	400	470	540	600	690	770
BASKETBALL	415	485	565	635	715	800
CANOEING	130	155	180	205	230	260
CLIMBING	360	420	485	550	620	710
CYCLING (LEISURE)	240	265	305	365	420	480
CYCLING (RACING)	510	600	690	780	870	980
DANCING (FAST)	310	365	420	475	535	600
DANCING (SLOW)	155	180	210	235	265	295
FISHING	185	220	255	290	320	365
GARDENING (DIGGING)	375	445	515	580	650	730
GARDENING (MOWING)	355	395	455	515	575	655
GOLFING	260	300	350	390	440	500
GYMNASTICS	280	315	360	405	455	515
HORSEBACK RIDING	200	235	270	305	340	399
IRONING	100	115	130	150	170	190
JUDO/KARATE	585	690	795	900	1005	1145

Figure A26 View/Edit Exercise Charts

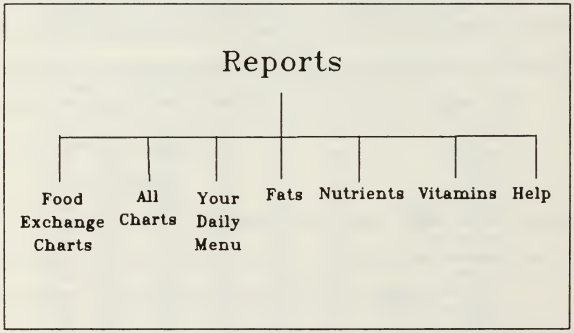

Figure A27 Nutrition/Exercise Level Three

4.3.9 Your Daily Menu

4.3.10 Fats

4.3.11 Nutrients

4.3.12 Vitamins

4.3.13 Minerals

4.3.14 Help

k. Level Three Structure

4.3.7 Food Exchange Charts

This report contains food compositions for a selected Food Exchange. A message will prompt you to enter the food exchange chart that you wish to print. (Figure A28)

4.3.8 All Charts

This report contains the entire Food Exchange data base. It lists foods and food compositions by food exchange category.

4.3.9 Your Daily Menu

This selection prints the daily menus designed with the Menu Design function. The user will be prompted for the patient's SSN. Once this data is entered the menu for the current day is printed. (Figure A29)

4.3.10 Fats

This report displays the nutritive values of foods in commonly used household measures. The user will be prompted for the food category to be entered. Once this is done, a report is generated. The report contains the following data: (Figure A30)

FOOD EXCHANGE CHARTS

July 10, 1989 Exchange Charts Grouped by Food Exchange Page 1

Food Description	Measure	Cal	Exchg Units Per Food P M F V O B	Pro	Car	Fat	Chl	Sod
FOOD EXCHANGE: B								
ANIMAL COOKIES	8 each	75	1	2	15		0	0
BAKED POTATO	1 ea.small	75	1	2	15		0	0
BEANS,Red or White	1 cup	75	1	2	15		0	0
BISCUIT (2")	1 each	120	1 1	2	15	5	0	0
BREAD	1 slice	75	1	2	15		0	0
BREAD,Low calorie	2 slice	75	1	2	15		0	0
BREADCRUMBS,Dry	0 cup	75	1	2	15		0	0
CEREAL,Cooked	1 cup	75	1	2	15		0	0
CEREAL,Dry	1 cup	75	1	2	15		0	0

Figure A28 Food Exchange Charts

Report prepared,
July 11, 1989

Page

Food	EX	Measure	Tot Cals	Total Exchange Units per Food: Pro	Milk	Frt	Veg	B&S	O&F	Tot Chls	Tot Sod
MENU PREPARED FOR: Steve Albert 11-Jul-89											
Meal: Br											
ANIMAL COOKIES	B	1.00 each	75					1.0		0	0
BACON	O	1.00 strip	45	0.0	0.0	0.0	0.0	0.0	1.0	0	0
BANANA	F	2.00 each	90	0.0	0.0	2.0	0.0	0.0	0.0	0	0
		Meal Totals:	210	0.0	0.0	2.0	0.0	1.0	1.0	0	0
Meal: Ln											
BEEF BRISKET	P	2.00 lb		2.0						0	0
		Meal Totals:	0	2.0	0.0	0.0	0.0	0.0	0.0	0	0
		Daily Totals:	210	2.0	0.0	2.0	0.0	1.0	1.0	0	0

Figure A29 Daily Menu

August 23, 1989 Grouped by Food Category Page 1

Food Description	Measure	Cals	Fat	Fatty Acids			Chols
				Sat	Mono	Poly	
FOOD CATAGORY: BEVERAGES							
BEER,Light	12.00 fl oz	95	0	0	0	0	0
BEER,Regular	12.00 fl oz	150	0	0	0	0	0
CLUB soda	12.00 fl oz	0	0	0	0	0	0
COFFEE,Brewed	6.00 fl oz	Tr	Tr	Tr	Tr.	Tr.	0

Figure A30 Fats

1. Food Description
2. Household Measure
3. Fat in grams
4. Fatty Acids as:
   a. Saturated in grams
   b. Mono-unsaturated in grams
   c. Polyunsaturated in grams
5. Cholesterol in milligrams

4.3.11 Nutrients

This report is similar to the one above. However, Nutrients contains the following data:

1. Food Description
2. Household Measure
3. Calories
4. Protein in grams
5. Carbohydrates in grams
6. Fat in grams
7. Cholesterol in milligrams
8. Sodium in milligrams

4.3.12 Vitamins

This report contains:

1. Food Description

2. Household measure
3. Calories
4. Vitamin A in international units
5. Vitamin C in milligrams
6. Thiamine
7. Riboflavin
8. Niacin

4.3.13 Minerals

This report contains:

1. Food Description
2. Household measure
3. Calories
4. Calcium in milligrams
5. Phosphorus in milligrams
6. Iron in milligrams
7. Potassium in milligrams
8. Sodium in milligrams
9. Percent water

5. Dictionary

This selection provides the user with an alphabetical listing of diabetic and medical terms and the corresponding definition.

This concludes the User's Manual.

BIBLIOGRAPHY

American Diabetes Association and American Dietetic Association, *Exchange Lists for Meal Planning*. 1986.

Boehringer Mannheim Corporation. *Merlin Diabetes Data Management System User's Manual (Version 1.0)*. 1988.

"Buyer's Guide:Relational Database [dbase III Plus, Paradox, DataEase, R:Base for DOS, Professional Oracle, Advanced Revelation: Special]", *Personal Computing*, v.12, pp.173-178, November 1989.

Ellenberg, M., "Chronic Complications of Diabetes Mellitus," *NY State Journal of Medicine*, pp. 2005-2014, December 1979.

Feder, Arlene S. "Counting on Computers," *Diabetes Forecast*, pp. 38-42, November 1988.

McMahon, Paula R.D., and Travis, Luther B. M.D., *Your Daily Meal Plan*. University of Texas Medical Branch Galveston, Texas. 1988.

Miastkowski, Stan. and Nick Baran,"Paradox 3, Neither Enigma Nor Riddle," *Byte*, pp. 109-111, February 1989.

Netzer, Corinne T. *The Complete Book of Food Counts*. Dell Publishing Co.,Inc., New York, N.Y. 1988.

Sprague and Carlson. *Building Effective Decision Support Systems*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 1982.

Travis, Luther B. *An Instructional Aid on Insulin-Dependent Diabetes Mellitus*. Stafford-Lowdon, Fort Worth, Texas. 1985.

Turban, E. *Decision Support and Expert Systems*. MacMillan Publishing Co., NY, NY. 1988.

United States Department of Agriculture Handbook Number 451. *Nutritive Value of Foods in Common Units*. Superintendent of Documents, U.S. Printing Office, Washington, D.C., 1988.

United States Department of Agriculture Home and Garden Bulletin Number 72. *Nutritive Values of Foods*. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 1981.

INITIAL DISTRIBUTION LIST

1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Professor Moshe Zviran (Code 54Zv) Naval Postgraduate School Monterey, California 93943-5002	1
4.	Professor Tarek Abdel-Hamid (Code 54Ah) Naval Postgraduate school Monterey, California 93943-5002	1
5.	Richard A. Blow 40190 San Carlos Place Fremont, CA 94539	2
6.	Steven P. Albert 805 2nd Street Pacific Grove, California 93950	1

Thesis
B5691 Blow
c.1 A personal-computer
based DSS for diabetes
control and monitoring.

6 NOV 90 36335
26 JUN 91
26 JUN 91

Thesis
B5691 Blow
c.1 A personal-computer
based DSS for diabetes
control and monitoring.

a5691
A personal-computer based DSS for diabet
3 2768 000 90743 0
DUDLEY KNOX LIBRARY